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Abstracts

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ECVP 2013 Abstracts

Sunday

PERCEPTION LECTURE

- **The Functional Organization of the Ventral Visual Pathway in Humans**
  N Kanwisher (McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, United States)

Over the last fifteen years, functional imaging studies in humans have provided a richly detailed view of the functional organization of the ventral visual pathway in humans. In this talk I will take stock of what we have learned so far, and attempt to identify the most important unanswered questions. In particular, functional imaging has powerfully complemented prior behavioral and neuropsychological work in enabling us to discover the major components of the processing machinery that holds our representation of the visual world. The most robust findings are a set of brain regions that respond selectively to faces, places, bodies, and objects. Each of these regions is found in approximately the same location in virtually every normal subject, thus constituting part of the fundamental architecture of the human visual mind and brain. Beyond this widely-replicated set of results, though, lie numerous controversies and unanswered questions. First, does the representation of a given object occupy much of the expanse of the ventral pathway (the "distributed" view), or are some objects primarily represented in a small number of focal regions? Here I will argue that although pattern analyses do show that many category-selective regions hold some information about nonpreferred stimuli, the important question is which of this information is used, that is, which plays a causal role in perception – a question that is hard to address with neuroimaging but that can be tackled with TMS, electrical stimulation, and patient studies. Second, how does the functional organization of the ventral pathway arise in development, and why do the functionally specific regions land where they do in the brain? Here I will argue that in contrast to widespread claims, much of the organization of the ventral pathway (including the FFA) is nearly adultlike by late childhood. These results underscore is the importance of looking at much younger children or even infants, something that is nearly impossible with fMRI in humans. Further, the deepest questions about the development of the ventral pathway concern the role of experience, and the question of whether an early-developing functional or structural organization instructs the later development of category-selective cortical regions – questions that are currently wide open. Third, we have not made enough progress on the central problem of characterizing the representations and computations that exist in each of these regions, a question that may require the temporal and neuron-level precision available only in animal models. Fourth, what is the connectivity of each of these regions to each other and the rest of the brain? Although clues are emerging from diffusion and resting functional studies, neither method is perfect, leaving this fundamental question largely unanswered. Perhaps the biggest open question concerning the functional organization of the ventral visual pathway is whether functionally distinctive regions are best thought of as discrete processors, or whether it makes more sense to consider the whole ventral pathway as a single processor in which each of these regions simply constitutes a local peak in the functional response. To the extent that the different regions have distinctive connectivity and cytoarchitecture, that would support the interpretation of these regions as distinct entities. On the latter view, the question would still remain of why that landscape would contain the particular replicable configuration it does, and what if any are the dimensions represented by axes of this broader 'map'.

BERNSTEIN TUTORIALS : COMPUTATIONAL NEUROSCIENCE MEETS VISUAL PERCEPTION

- **A1: Programming Bricolage for Psychophysicists: Essential Tools and Best Practices for Efficient Stimulus Presentation and Data Analysis**
  T Zito[1], M Hanke[2] ([1]Imperial College London, Germany; [2]University of Magdeburg, Germany)

This tutorial provides an opportunity to fill a few gaps in the typical training of a psychophysicist. It will help to learn programming scripts for stimulus presentation and data analysis efficiently – exploiting

a computer instead of fighting it. We will demonstrate best practices and easy development tools that make coding faster and more robust, as well as the result more functional and reusable for the next experiment and the next student. We expect our audience to be familiar with at least one programming language or environment (Python, Matlab, Labview, IDL, Mathematica, C, Java, to just name a few) and be willing to change their attitude towards software development.

- **A2: Modelling Vision**

  H Neumann[1], L Schwabe[2] ([1]University of Ulm, Germany; [2]University of Rostock, Germany)

This tutorial is structured into two parts that will be covered by a morning and an afternoon session. In the morning session we first motivate the role of models in vision science. We show that models can provide links between experimental data from different modalities such as, e.g., psychophysics, neurophysiology, and brain imaging. Models can be used to formulate hypotheses and knowledge about the visual system that can be subsequently tested in experiments and, in turn, also lead to model improvements. To some extent, however, modeling vision is indeed an art as the visual system can be described at various levels of abstraction (e. g. purely descriptive vs. functional models) and different spatial and temporal granularity (e. g. visually responsive neurons vs. brain-wide dynamics, or perceptual tasks vs. learning to see during development). Therefore, throughout the tutorial we address questions such as "How to chose a model for a given question?", and "How to compare different models?". Based on this general introduction we will review phenomenological models of early and mid-level vision, addressing vision topics such as perceptual grouping, surface perceptions, motion integration, and optical flow. We discuss a few specific models and show how they can be linked to data from visual psychophysics, and how they may generalize to other visual features. In line with this year's ECVP focus on "Computational Neuroscience", we also discuss how such models can be used to constrain hypotheses about the neural code in the visual system, or to make implicit assumptions about these codes explicit. In the afternoon session we first consider neurodynamical models of visual processing and show how cortical network models can affect the interpretation of psychophysical and brain imaging data. We then show how physiological and anatomical findings, as summarized by neurodynamical models, can be used to design experiments and stimuli for visual psychophysics. We then also consider the modeling of vision via modeling learning in the visual system. The rational behind such modeling approaches is that a proper learning algorithm based on first principles will produce models of visual systems when stimulated with natural stimuli. The advantages and pitfalls of such normative modeling will be discussed. Finally, we consider models of higher-level form and motion processing, e.g. biological motion or articulated motion, and compare the performance of such models with human performance and recent advances in visual computing such as markerless motion capture.

- **B1: Introduction to Matlab and PsychophysicsToolbox**

  M Kleiner (Max Planck Institute for Biological Cybernetics, Tübingen, Germany)

Psychtoolbox-3 is a cross-platform, free and open-source software toolkit for the Linux, MacOSX and Windows operating systems. It extends the GNU/Octave and Matlab programming environments with functionality that allows to conduct neuroscience experiments in a relatively easy way, with a high level of flexibility, control and precision. It has a number of coping mechanisms to diagnose and compensate for common flaws found in computer operating systems and hardware. It also takes unique advantage of the programmability of modern graphics cards and of low-level features of other computer hardware, operating systems and open-source technology to simplify many standard tasks, especially for realtime generation and post-processing of dynamic stimuli. This tutorial aims to provide an introduction into the effective use of Psychtoolbox. However, participants of the tutorial are encouraged to state their interest in specific topics well ahead of time, so i can try to tailor large parts of the tutorial to the actual interests of the audience if there happens to be clusters of common wishes. Ideally this will be interactive rather than a lecture. Wishes can be posted to the issue tracker at GitHub (https://github.com/kleinerm/Psychtoolbox-3/issues/new) with the label [ecvp2013], or via e-mail to mario.kleiner.de@gmail.com with the subject line [ecvp2013ptb].

- **B2: Introduction to Python and PsychoPy**

  J Peirce (Nottingham University, United Kingdom)

This tutorial will introduce the basics of how to use PsychoPy and Python for visual neuroscience. PsychoPy is open-source, platform independent, easy to install and learn and provides an extremely flexible platform for running experiments. It has the unique advantage of both a scripting interface (similar to Psychtoolbox but using the Python language) and a graphical interface requiring little or

no programming (ideal for teaching environments and simpler experiments). This tutorial will get you started with both interfaces, and show how the two can be used together by building a basic experiment visually and then customizing it with code. If possible, bring along a laptop with PsychoPy installed and we can make it more of an interactive workshop, with live exercises.

- **B3: Introduction to fMRI data analysis and classification**
  J Heinzle (University Zurich and ETH Zurich, Switzerland)

This tutorial is addressed to people interested in, but not yet familiar with, analysing functional magnetic resonance imaging (fMRI) data. It will introduce the key basics of fMRI data analysis and classification. The tutorial will start with a brief introduction to the physics and physiology underlying fMRI measurements. The main part will then be devoted to the analysis of fMRI data, focussing particularly on visual experiments. Finally, we will give a short overview of novel approaches using fMRI data for classification. The goal is to provide an overview over the general principles of fMRI data analysis and classification, and the material presented is not tied to any specific analysis software. We will highlight relevant references and emphasize potential pitfalls. We hope to provide participants with all the necessary ingredients to embark on their own analysis of fMRI data.

- **B4: Introduction to Single-Trial EEG analysis & Brain-Computer Interfacing**
  B Blankertz (Technical University of Berlin, Germany)

The aim of this lecture is to provide an illustrative tutorial on methods for single-trial EEG analysis. Concepts of feature extraction and classification will be explained in a way that is accessible also to participants with less technical background. Nevertheless all techniques required for state-of-the-art Brain-Computer Interfacing will be covered. The presented methods will be illustrated with concrete examples from the Berlin Brain-Computer Interface (BBCI) research project.

- **B5: Introduction to Kernel Methods**
  F Jäkel (University of Osnabrück, Germany)

The abilities to learn and to categorize are fundamental for cognitive systems, be it animals or machines, and therefore have attracted attention from engineers and psychologists alike. Early machine learning algorithms were inspired by psychological and neural models of learning. However, machine learning is now an independent and mature field that has moved beyond psychologically or neurally inspired algorithms towards providing foundations for a theory of learning that is rooted in statistics. Here, we provide an introduction to a popular class of machine learning tools, called kernel methods. These methods are widely used in computer vision and modern data analysis. They are therefore potentially interesting for vision research, too. However, reading about kernel methods can sometimes be intimidating because many papers in machine learning assume that the reader is familiar with functional analysis. In this tutorial, I give basic explanations of the key theoretical concepts that are necessary to be able to get started with kernel methods - the so-called kernel trick, positive definite kernels, reproducing kernel Hilbert spaces, the representer theorem, and regularization.

- **B6: Statistics of Signal Detection Models**
  K Knoblauch (Inserm 0846 Stem-Cell and Brain Research Institute Bron, France)

This tutorial will focus on the statistical tools to analyze and to model psychophysical experiments within the framework of Signal Detection Theory. This includes choice experiments (detection, discrimination, identification, etc.) and rating scale experiments with ROC analyses. In many cases, the decision rule underlying these paradigms is linear, thereby permitting the analyses to be simplified to a Generalized Linear Model (GLM). Rating scales, similarly, are analyzed by using ordinal regression models with cumulative link functions. With these approaches, we can define straight-forward procedures to fit the data, to test hypotheses about them, to obtain confidence intervals, etc. Diagnostic plots and tests will be used to evaluate goodness of fit and to explain some potential pitfalls that can occur in the data. Most off-the-shelf software packages now include tools for performing GLMs, thus, making it easy to implement these tests and procedures. Examples will be shown using the R programming environment and language (http://www.r-project.org/). Extensions of these models to include random effects allow estimation and control for observer and stimulus variability. Finally, an example will be shown of this approach with a paradigm for measuring appearance. Background reading includes the recent books "Modeling Psychophysical Data in R", K. Knoblauch & L. T. Maloney, 2012, Springer, (for R users) and "Psychophysics: A Practical Introduction", F. A. A. Kingdom & N. Prins, 2010, Academic Press (for matlab users).

◆ **B7: Classification images**

S Barthelmé (University of Geneva, Switzerland)

A large part of vision science is about figuring out the rules that govern perceptual categorisation. What makes us see a person as male or female? A pattern as symmetric or asymmetric? A smile or a frown on a face? Classification images (Ahumada and Lovell, 1971), use noise to uncover the rules defining a perceptual category. Adding a moderate amount of noise to the picture of a smiling face will produce a random stimulus, essentially a "perturbed" version of the original: still identifiable as a face, but with altered features (Kontsevich and Tyler, 2004). Depending on the exact pattern of the noise, the perturbed face will sometimes look just as smiling as the original, sometimes distinctively less so. Viewed geometrically, what this means is that the added noise sometimes takes the original stimulus across the smiling/unsmiling boundary. The intuition behind the original technique is that by looking at those noise patterns that lead to a response change and comparing to those that do not, we should be able to characterise the features that the visual system uses to decide whether a face is smiling or not. In this tutorial I will introduce this classical technique and a number of applications, but I will focus especially on setting a broader context. Although classification images are native to psychology, they have close cousins in many areas of science (Murray, 2011). We will see that classification images have interesting ties to a range of concepts and techniques across the disciplines, from Generalised Linear Models in statistics, to compressed sensing in computer science. Putting classification images in context helps us understand why they work, when they work, and how they can be extended. Ahumada, A. J. and Lovell, J. (1971). Stimulus features in signal detection. The Journal of the Acoustical Society of America, 49(6B):1751-1756. Murray, R. F. (2011). Classification images: A review. Journal of vision, 11(5).

◆ **B8: Statistical Modelling of Psychophysical Data**

J Macke (Max Planck Institute for Biological Cybernetics, Tübingen, Germany)

In this tutorial, we will discuss some statistical techniques that one can use in order to obtain a more accurate statistical model of the relationship between experimental variables and psychophysical performance. We will use models which include the effect of additional, non-stimulus determinants of behaviour, and which therefore give us additional flexibility in analysing psychophysical data. For example, these models will allow us to estimate the effect of experimental history on the responses on an observer, and to automatically correct for errors which can be attributed to such history-effects. By reanalysing a large data-set of low-level psychophysical data, we will show that the resulting models have vastly superior statistical goodness of fit, give more accurate estimates of psychophysical functions and allow us to detect and capture interesting temporal structure in psychophysical data. In summary, the approach presented in this tutorial does not only yield more accurate models of the data, but also has the potential to reveal unexpected structure in the kind of data that every visual scientist has plentiful– classical psychophysical data with binary responses.

◆ **B9: Attractor Networks and the Dynamics of Visual Perception**

J Braun[1], G Deco[2] ([1]Otto-von-Guericke-University Magdeburg, Germany; [2]Universitat Pompeu Fabra, Barcelona, Spain)

First principles of statistical inference suggest (e.g., Friston, Breakspear, Deco, 2012) that visual perception relies on two interaction loops: a fast ‘recognition loop’ to match retinal input and memorized world models and a slow ‘learning loop’ to improve these world models. Focusing on the fast loop, we try to make these abstract notions fruitful in terms of novel experimental paradigms and observations. The first half of the tutorial reviews the activity dynamics of attractor networks at different space-time scales – especially mesoscopic models of cortical columns and groups of columns and macroscopic models of whole-brain dynamics – and the second half compares the dynamics of perceptual decisions in the context of choice tasks, multi-stable percepts, and cooperative percepts. We argue that only a combination of principled models of collective neural dynamics and careful empirical studies of perceptual dynamics can guide us towards a fuller understanding of the principles and mechanisms of visual inference.

◆ **B10: Bayesian Methods and Generative Models**

J Fiser (Central European University Budapest, Hungary)

In the last two decades, a quiet revolution took place in vision research, in which Bayesian methods replaced the once-dominant signal detection framework as the most suitable approach to modeling visual perception and learning. This tutorial will review the most important aspects of this new framework

from the point of view of vision scientists. We will start with a motivation as to why Bayes, then continue with a quick overview of the basic concepts (uncertainty and probabilistic representations, basic equations), moving on to the main logic and ingredients of generative models including Bayesian estimation, typical generative models, belief propagation, and sampling methods. Next we will go over in detail of some celebrated examples of Bayesian modeling to see the argument and implementation of the probabilistic framework in action. Finally, we will have an outlook as to what the potential of the generative framework is to capture vision, and what the new challenges are to be resolved by the next generation of modelers.

SATELLITE : VISION OF ART - ART OF VISION

- **Art and aesthetics: challenges for neuroscience**
  B Conway (Neuroscience Program, Wellesley College, Wellesley & Department of Neurobiology, Harvard Medical School, Boston, MA, United States; e-mail: bconway@wellesley.edu)

Works of art are the product of the complex neural machinery that translates physical light signals into behavior, experience and emotion. The brain mechanisms responsible for vision and perception have been sculpted during evolution, and further modified by cultural exposure and development. Recent developments in neuroscience have come tantalizingly close to tackling long-standing questions of aesthetics. In my presentation, I will consider what questions this new field is poised to answer, and will attempt to underscore the substantial differences between beauty, art and perception, terms often conflated by "aesthetics". Although I will touch upon adjacent fields of neuroscience such as sensation, perception, attention, reward, learning, memory, emotions, and decision making, where discoveries will likely be informative, the bulk of my presentation will focus on a close examination of artists' paintings and practices, representing a return to the original definition of aesthetics (sensory knowledge). This examination aims to achieve insight into the discoveries and inventions of artists and their impact on culture, sidestepping the thorny issues of what constitutes beauty. In particular, I will address color contrast, which poses a challenge for artists: a mark situated on an otherwise blank canvas will appear a different color in the context of the finished painting. How do artists account for this change in color during the production of a painting? In the broader context of neural and philosophical considerations of color, I discuss the practices of several modern masters, including Henri Matisse, Paul Cézanne, Claude Monet, and Milton Avery, and suggest that the strategies they developed not only capitalized on the neural mechanisms of color, but also influenced the trajectory of western art history.

- **The meaning of colour in art and vision science**
  A Hurlbert (Institute of Neuroscience, Newcastle University, United Kingdom; e-mail: anya.hurlbert@newcastle.ac.uk)

The 'disegno vs colore' debate in art history mirrors a divide in the scientific approach to the understanding of human visual perception. In the mid-1800s, the Poussinistes argued for the dominance of drawing, line and form, against the Rubenistes' championing of the sensual, dramatic – but ultimately unreliable – properties of colour. Likewise, early theories of visual processing proposed that colour was segregated from form, and much of what we understand about the perception of objects – their motion, depth, and texture – has been learned from the analysis of images devoid of colour. Although it is now accepted that the neural processing of colour and form converges early in visual processing, the two attributes are still often treated as distinct in behavioural studies. Theories of visual object recognition, for example, treat colour as separable from and secondary to shape in signalling object identity. The 20th century abstract artists also release colour from form, but celebrate colour as having its own identity. In doing so, the abstract tradition also faces the challenge of conjuring up the multiple modalities that colour possesses: a surface attribute, tied to the material properties of objects, as well an extended property of voids, volumes, and lights. In fact, the genius of every painter is to capture with pigments – limited by subtractive mixing – this variety of modes of colour and material appearance. In this talk, I will trace the outlines of the colour-form debate using examples from key artists, describe some of the ways pigments have been used to capture colour modes, and use the duality of art and vision science to illustrate the fundamental phenomena of human colour perception. For example, JMW Turner himself evolved from a painter obsessed with light, shade and geometry into one consumed by colour; as he aged, his use of colour become freer, his line less pronounced, his subject matter more primitive and abstract. The abundant use of yellows and blues in Turner's later works echoes Poussin's use of the same colours – those "which most participate in light and air" (Le Brun 1667). The colour palettes

of both reflect the fact that the human visual system has adapted to its environment and captured the essential variations of daylight and natural objects in its neural coding of colour. Turner's love of the sky and its colours also points to the natural development of affective responses to colour – these are also fundamental to human colour perception and may arise from the emotional responses to objects to which particular colours are normally attached. Diagnostic colours of familiar colours also give rise to memory colours, which are embedded in neural representations and affect our immediate perception of incoming stimuli. Lastly, I will consider the role of colour constancy – the perceptual phenomenon by which object colours remain constant under changing illumination spectra – in the production and display of paintings, using as examples Monet's series paintings as well as recent laboratory work on the perception and optimisation of chromatic illuminations.

- **Painting Perception**
  R Pepperell (Cardiff School of Art and Design, Cardiff, United Kingdom;
  e-mail: pepperell@ntlworld.com)

For many centuries artists have studied the nature of visual perception in order to better understand, and therefore better represent, how they see the world. I will argue that in doing so they have discovered several interesting features of visual perception that are yet to be fully investigated by the relevant sciences. In this talk I will discuss some of these features and show how I and other artists have explored them through painting and drawing. I will present the results of some recent empirical studies on pictorial double vision and the depiction of the full field of view. Pictorial double vision, which simulates the everyday experience of physiological diplopia, is not generally recognised as one of the monocular depth cues. Yet some artists have used it in their paintings and drawings, and we have shown that under certain conditions it can effectively enhance the perception of depth in pictures (Pepperell and Ruschkowski, in press). The problem of how to fit the contents of the field of view into the boundary of a picture while retaining the perceived scale of the objects being depicted is one that has long troubled artists. Zoom out too far from the object of interest and it shrinks into insignificance; zoom in too close and the surrounding space is cropped. I will argue certain artists have found a unique solution to this problem that may also tell us something about the visual perception of space. I will close by considering the implications of this work for the future of image making and by stressing the need for art and science to work closely together in order to widen and deepen our knowledge of visual experience.

- **Movies, motion and emotion: brain function underlying perception of dynamic stimuli**
  A Bartels (Centre for Integrative Neuroscience (CIN), Vision & Cognition Lab, University of Tübingen, Germany; e-mail: andreas.bartels@tuebingen.mpg.de)

Not all art is static, some of it is designed to be explored through self- or object motion, such as sculptures, installations and movies. Our key interest lies in understanding high-level processing of visual motion. Even though we are not explicitly studying art, our interest led us to study cinematic movies and motion-illusions that may count as modern forms of art. Using these stimuli, or controlled stimuli that were inspired from them, allowed us to gain fundamental insights in neural mechanisms related to processing dynamic visual stimuli. Our brains are experts in processing dynamic visual input: we rarely ever sit still or stop moving our eyes, and even if we did, there is enough motion in our environment to keep the signals reaching our retinae changing. Despite decades of research on visual motion processing, surprisingly little is known about processes that allow us to perceive the world as stable, and to segregate self-induced motion from external motion. Cinematic films however use and rely on simulated self-motion to put us right into the role of an active observer on site. In my talk I will present several studies from our lab that shed some light on neural substrates involved in solving the self- vs. external motion problem that we addressed using feature movies and controlled visual stimuli. Since self-motion leads to spatial self-displacement, we complemented our motion studies with ones looking at the representation of ego-centric space in the brain that I will briefly touch on. I will also show evidence on mechanisms helping us to use motion cues to 'bind' and recognize global Gestalt from local cues, using a beautiful illusion, and present new evidence on how distinct aspects of face-motion are extracted in distinct face-processing regions to extract emotional meaning from motion. If time permits, I may digress briefly to discuss the relationship between motion and color in both perception and neural integration. This will be a neuroscience talk – but hopefully nevertheless relevant to artists, as most fundamental insights into the visual brain are relevant for artists, just as most relevant visual art provides insights into vision.

- **How we look and what we know determines how we see and appreciate art**

J Wagemans (Laboratory of Experimental Psychology, University of Leuven (KU Leuven), Belgium; e-mail: johan.wagemans@ppw.kuleuven.be)

Both visual perception and art appreciation are known to be influenced by a mixture of "bottom-up" and "top-down" factors. In art perception and appreciation, Gombrich's "beholder's share" is now widely acknowledged, and recent frameworks have tried to include all relevant components and influencing factors (e.g., Leder et al., 2004, British Journal of Psychology, 95, 489-508). Against this background, we have used a variety of research methods (eye movement recordings, rating scales, questionnaires and qualitative interviews) to try to understand how visual perception affects aesthetic appreciation in both naïve and expert viewers. I will illustrate this approach with some research projects in collaboration with three contemporary artists: Wendy Morris, Ruth Loos, and Anne-Mie Van Kerckhoven. Findings about ambient versus focal viewing styles will be related to the viewer's background and purpose, and their effects on appreciation will be demonstrated. I will also discuss some of the advantages of working with living artists rather than with classic art works.

- **Neuroscience, visual illusions, and art – not necessarily a happy union**

M Bach (Eye Hospital, University of Freiburg, Germany; e-mail: michael.bach@uni-freiburg.de)

I will explore relations between neuroscience –specifically visual phenomena– and art, both fine arts and commercial arts. Transfers from neuroscience to art have occurred with a range of effectiveness. Amongst the successful transfers I count Magritte's 'Carte blanche', Penrose, Penrose & Escher, and Casati's 'rabbit shadow'. Forensic controversy resulted from transferring Harmon & Julesz' 'The recognition of faces' by Dali. Amongst the unsuccessful transfers, I count the San Lorenzo mosaic interpretation and 'café wall paintings'. Puritan censoring and other constraints affect the transfer of neuroscience to art, which I will illustrate in a "Silence of the lambs" movie poster and through an experience with Georgia's school authorities. One could count as "translational research" transfers that have appeared in advertisement and fashion. As examples of successful ones, I will demonstrate Magnum and Vin Uno advertisement posters. Among the doubtful examples are shading in clothing that strives to render body silhouettes more (or less) curvaceous, and for an unsuccessful example I will show the "leopard" car advertisement, based on the Simon gorilla.I will finish up by suggesting that it may not really be useful for artistic endeavours to be too academic. Von Kleist (1810, "Über das Marionettentheater") gave a beautiful example of a dancer loosing his graceful and enchanting pose when trying to render it wilfully. As more concrete examples I suggest the Golden Ratio, which has largely ex post been read into art, and the standard explanation of pointillism, which falls apart by simply examining a painting close up. This exploration has led me to assert that neuroscience contributes little, if anything, to the understanding of art: Full scientific understanding would lead to rules how to create art, and art created solely by rules lacks art.

Monday

SYMPOSIUM : THE SCOPE AND LIMITS OF VISUAL PROCESSING UNDER CONTINUOUS FLASH SUPPRESSION

- **Probing unconscious perception: a comparison of CFS, masking and crowding**

S Kouider (CNRS and Ecole Normale Supérieure, France; e-mail: sid.kouider@ens.fr)

A major issue in psychology concerns the nature of unconscious processes and how they differ from conscious processes. Research on this issue has relied on various types of methodology and provided various results with sometimes contrary implications on the extent and limits of unconscious perceptual processes. In this talk I will provide an overview of the functional and neurophysiological characteristics underlying continuous flash suppression (CFS), masking and crowding. I will also present experimental studies from our group directly comparing the strength of nonconscious influences obtained across these three methods. I will argue for the necessity of rigorous comparisons between the different methods employed to prevent perceptual awareness.

- **A novel technique to study visual processing in the objective absence of awareness**

M Rothkirch[1], P Sterzer[2] ([1]Department of Psychiatry, Charité - Universitätsmedizin Berlin, Germany; [2]Visual Perception Laboratory, Charité - Universitätsmedizin Berlin, Germany; e-mail: marcus.rothkirch@charite.de)

The question if and how human behavior can be guided by visual information that the individual is unaware of is still the subject of ongoing research. Critically, when asked for their subjective experience, observers may deny seeing a stimulus despite being partially or even fully aware of it, because subjective reports of (un)awareness depend on observers' response criterion. By contrast, an objective measure of awareness is uncontaminated by such response biases. Here we present a novel technique for the examination of goal-directed behavior in the objective absence of awareness. During visual search for a stimulus rendered invisible with continuous flash suppression, we performed eyetracking to determine whether participants' eye movements were influenced by the invisible stimulus. Participants' objective absence of awareness was ensured by chance accuracy in a concurrently performed manual 2AFC task. Contrary to their manual responses, participants' eye movements were more frequently directed towards invisible stimuli than would be expected by chance. Our results demonstrate (1) that goal-directed behavior can be performed even in the objective absence of awareness, and (2) that our technique provides a suitable tool to study which stimulus features can guide human behavior even when they do not get access to conscious awareness.

- **Posing for awareness: Proprioception modulates access to visual consciousness in a continuous flash suppression task**

R Salomon, M Lim, B Herbelin, O Blanke (Center for Neural Prosthetics, Lab of Cognitive Neuroscience, EPFL, Switzerland; e-mail: roy.salomon@epfl.ch)

The rules governing the selection of which sensory information reaches consciousness are yet unknown. Of our senses, vision is often considered to be the dominant sense and the effects of bodily senses, such as proprioception, on visual consciousness are frequently overlooked. Here, we demonstrate that the position of the body influences visual consciousness. We induced perceptual suppression by using continuous flash suppression (CFS). Participants had to judge the orientation of a target stimulus embedded in a task irrelevant picture of a hand. The picture of the hand could either be congruent or incongruent with the participants' actual hand position. When the viewed and the real hand positions were congruent perceptual suppression was broken more rapidly than during incongruent trials. Our findings provide the first evidence of a proprioceptive bias in visual consciousness, suggesting that proprioception not only influences own body perception and consciousness, but also visual consciousness.

- **Learning to detect but not to grasp suppressed visual stimuli**

K Ludwig[1], P Sterzer[1], N Kathmann[2], V H Franz[3], G Hesselmann[1] ([1]Visual Perception Laboratory, Charité - Universitätsmedizin Berlin, Germany; [2]Klinische Psychologie, Humboldt-Universität zu Berlin, Germany; [3]Allgemeine Psychologie, Universität Hamburg, Germany; e-mail: karin.ludwig@charite.de)

One feature of continuous flash suppression (CFS) is its potency to render stimuli invisible for up to seconds (Tsuchiya & Koch, 2005). Here, we exploited this feature to test a central implication of the two-visual-systems hypothesis (TVSH), namely that the dorsal visuomotor system can make

use of invisible information and direct grasping movements (vision-for-action), whereas the ventral system (vision-for-perception) cannot, whereby conscious reports are unaffected by invisible information (Milner & Goodale, 1995). In two experiments using CFS, subjects were asked to grasp for invisible bars of different sizes (exp. 1, N=5) or orientations (exp. 2, N=6), or to report both measures verbally. Target visibility was measured trial-by-trial using the perceptual awareness scale (PAS). We found no evidence for the use of invisible information by the visuomotor system despite extensive training (600 trials) and the availability of haptic feedback. Subjects neither learned to scale their maximum grip aperture to the size of the invisible stimulus, nor to align their hand to its orientation. Careful control of stimulus visibility across training sessions, however, revealed a robust tendency towards decreasing perceptual thresholds under CFS. We will discuss our results with respect to conflicting earlier findings and the TVSH.

- **Unconscious processing under CFS: Getting the right measure**
  T Stein (CIMeC, University of Trento, Italy; e-mail: timo@timostein.de)

Unconscious visual processing is typically investigated by contrasting a direct measure of stimulus awareness with an indirect measure of stimulus processing (e.g. adaptation aftereffect). Unconscious processing is inferred when no sensitivity is found in the direct measure, but some sensitivity in the indirect measure. Applying this classic dissociation paradigm, our research on adaptation aftereffects shows that under continuous flash suppression (CFS) only simple stimulus attributes can be processed unconsciously, whereas the processing of complex stimulus properties requires awareness. Recently, this notion has been challenged by findings obtained with a new technique that circumvents the use of an indirect measure and aims at directly measuring unconscious processing. In this breaking CFS (b-CFS) paradigm, differential unconscious processing during CFS is inferred from the time stimuli need to overcome CFS and emerge into awareness. B-CFS is highly sensitive to differences between complex stimuli in their potency to gain access to awareness. However, our data show that such effects need not be specific to CFS, but could reflect non-specific differences in detection thresholds. Therefore, b-CFS cannot provide evidence for unconscious processing specific to CFS. Thus, at present only the classic dissociation paradigm is capable of informing theories of unconscious information processing under interocular suppression.

- **What individual differences in suppression by CFS tell us about social evaluation of faces**
  B Bahrami[1], S Getov[2], J Winston[2], R Kanai[3], G Rees[1] ([1]UCL Institute of Cognitive Neuroscience, University College London, United Kingdom; [2]Welcome Centre for Neuroimaging, University College London, United Kingdom; [3]School of Psychology, University of Sussex, United Kingdom; e-mail: bbahrami@gmail.com)

Since its introduction, Continuous Flash Suppression has been extensively used as a window into preconscious visual processing (Stein, Hebart & Sterzer (2011) . Breaking continuous flash suppression: A new measure of unconscious processing during interocular suppression? Frontiers in Human Neuroscience, 5, 167). We too, have recently taken this approach to ask whether evaluation of faces on social dimensions of trust and dominance is restricted to conscious appraisal or, rather happen at a preconscious level. We will present data showing that by capitalizing on the individual differences between observers in the time they take to overcome suppression by CFS, it is possible to identify a number of observer-specific personality traits as well as markers of local brain structure that are instructive in helping us understand the neural basis of social evaluation of faces.

SYMPOSIUM : PERCEPTUAL MEMORY AND ADAPTATION: MODELS, MECHANISMS, AND BEHAVIOR

- **Adaptive coding in visual cortical networks**
  V Dragoi (Univ. of Texas-Houston Medical School, TX, United States; e-mail: v.dragoi@uth.tmc.edu)

Understanding the rules by which brain networks represent incoming stimuli in population activity to influence the accuracy of perceptual responses remains one of the deepest mysteries in neuroscience. We have embarked on a set of projects to investigate the real-time operation of neuronal networks in multiple brain areas and their capacity to undergo adaptive changes and plasticity. What are the fundamental units of network computation and the principles that govern their relationship with behavior? By employing state-of-the-art electrophysiological techniques we were able to record from large pools of cells in the non-human primate brain while animals performed a fixation task. We found that spatio-temporal

correlations between neurons could act as an active 'switch' to control network performance in real time by modulating the communication between neurons. We believe that 'cracking' the mysteries of the population code will offer unique insight into a network-based mechanistic explanation of behavior and new therapeutic solutions to cure brain dysfunction.

- **Mechanisms of adaptation in macaque inferior temporal cortex**
  R Vogels (KU Leuven, Belgium; e-mail: rufin.vogels@med.kuleuven.be)

Repetition of a stimulus reduces the responses of inferior temporal (IT) cortical neurons. Several neural models have been proposed to explain this repetition suppression or adaptation effect. We compared predictions derived from these models with adaptation effects of spiking activity in macaque IT cortex. Contrary to sharpening but in agreement with fatigue models, repetition did not affect shape selectivity. The degree of similarity between adapter and test shape was a stronger determinant of adaptation than was the response to the adapter. The spiking and LFP adaptation effects agreed with input-, but not response-fatigue models. Second, we examined whether stimulus repetition probability affects adaptation, as predicted from a top-down, perceptual expectation or prediction error model. Monkeys were exposed to 2 interleaved trials, each consisting of 2 identical (rep trial) or 2 different stimuli (alt trial). Repetition blocks consisted of 75% (25%) of rep (alt) trials and alternation blocks had the opposite repetition probabilities. For spiking and LFP activities, adaptation did not differ between these blocks. This absence of a repetition probability effect on adaptation agrees with bottom-up, fatigue-like mechanisms. Finally, we will discuss the effect of adaptation on object encoding in IT both at the single cell and population level.

- **History effects in visual perception**
  P Mamassian (Lab Psychologie Perception, CNRS & Université Paris Descartes, France; e-mail: pascal.mamassian@parisdescartes.fr)

Visual perception is not merely determined by the current sensory stimulus, it is also influenced by previous visual decisions. History effects in visual perception have been demonstrated with adaptation and the resulting after-effects, with implicit perceptual memory influencing binocular rivalry and ambiguous figures, with sequential effects from past trials in repetitive decisions, and with implicit learning of visual statistical regularities. Recently, we found that stimuli presented 10 minutes in the past can also influence the current perceptual decision (Chopin & Mamassian, 2012, Current Biology). For instance, seeing more often a stimulus with an orientation A rather than B several minutes ago introduces a bias to perceive the orientation A, while seeing more often A a few seconds ago produces the opposite bias. We believe that the monitoring of remote history statistics contributes to the recalibration of the visual system. This proposal is discussed in the context of the other history effects in visual perception.

- **Perceptual memory in ambiguous vision: A paradigmatic case of perceptual inference**
  P Sterzer (Visual Perception Laboratory, Charité - Universitätsmedizin Berlin, Germany; e-mail: philipp.sterzer@charite.de)

When ambiguous images that normally cause alternation between two or more perceptual states are presented intermittently, perception tends to lock into one interpretation. This stabilization of perception has been suggested to indicate a form of perceptual memory. I will argue that the stabilization of perception across multiple presentations of an ambiguous stimulus is a paradigmatic case of perceptual inference and can be used to probe inferential mechanisms in perception. During repeated exposure of a stimulus endogenous predictions are automatically built up and facilitate perceptual inference at each recurrence of the stimulus. In the case of ambiguous stimuli, the incorporation of these predictions based on previous perceptual outcomes results in the stabilization of perception. I will present behavioral data showing that the experimental manipulation of endogenous predictions through associative learning can influence the stability of perception. Moreover, I will show that perceptual stability in ambiguous vision can be used to probe impairments in perceptual inference, e.g., in delusion-prone individuals. Finally, I will relate these ideas to functional neuroimaging findings that provide a neural basis for the stabilization of perception in ambiguous vision.

- **Separate cortical networks for perceptual memory and perceptual adaptation**
  C Schwiedrzik (Laboratory of Neural Systems, The Rockefeller University, NY, United States; e-mail: cschwiedrz@rockefeller.edu)

It is well accepted that perception strongly depends on previous experience. However, it remains unclear how the brain entertains two modes in which previous experience affects perception: an attractive

effect called 'perceptual memory' (PM), which increases the likelihood to perceive the same again, and a repulsive effect called 'perceptual adaptation' (PA), which increases the likelihood to perceive something else. We combined functional magnetic resonance imaging and psychophysics in humans to test how the brain entertains these two processes without mutual interference. We found that although affecting our perception concurrently, PM and PA map into distinct cortical networks: a widespread network of higher-order visual and fronto-parietal areas was involved in PM, while PA was confined to early visual areas. Our data refute theoretical models that either explain PM and PA with a single mechanism or with two separate mechanisms that, however, co-localize to the same early sensory area. In turn we propose that the areal and hierarchical segregation may enable the brain to maintain the balance between stabilization and exploring new information. A Bayesian model which implements perceptual memory as changes in the prior and adaptation as changes in the sensory evidence reproduces the behavioral data.

SYMPOSIUM : SYNERGISTIC HUMAN COMPUTER INTERACTION (HCI)

- **Attentive Computing – Using Eye Gaze for Unintrusive Services**
  T Kieninger (Knowledge Management dept., DFKI GmbH, Germany;
  e-mail: thomas.kieninger@dfki.de)

In the recent years, eyetracking devices have made tremendous improvements wrt. their accuracy, the comfort of use and also the costs. These trends open up new possibilities apart from their classical application domains in e.g. customer analysis where only little number of devices are used for one-time experiments. The DFKI has investigated to what degree eye trackers can improve our daily lives, assuming that with raising sales figures these devices might soon become affordable to everyone. Under the label "Text 2.0" we developed a framework that observes the user when reading text on a computer screen using a desktop eye tracker. It not only recognizes which textline or word a user currently looks at, but also if he is skimming over a text, or getting stuck at some word. These mechanisms have led to a series of applications and proactive services ranging from entertainment to education. In parallel, we worked with mobile eye trackers which permit services apart from monitor screens. By analyzing the provided scene image together with eye fixations and optional movement sensors we built several prototypes that anticipate when the user shows interest to some object. Sample applications are the "MuseumGuide2.0" or an automatic "Visual Diary".

- **Perceptual and Adaptive Learning Technologies in Education and Training**
  P Kellman (University of California, Los Angeles, CA, United States;
  e-mail: kellman@cognet.ucla.edu)

Recent in perceptual learning offers remarkable potential to improve almost any kind of education or training. I will discuss recent innovations in perceptual learning and adaptive learning technologies. Whereas learning in educational settings most often emphasizes declarative and procedural knowledge, studies of expertise point to crucial components of learning that involve improvements in the extraction of information. I will describe research that uses perceptual learning modules (PLMs) in computer-based learning technology to address challenges in learning in mathematics, science, medicine, and aviation, In the second part of the talk, I discuss the novel ARTS (adaptive response-time based sequencing) system, an adaptive learning system that markedly improves interactive learning by using both accuracy and speed data, and concurrently implementing a number of laws of learning and mastery. PLMs and the ARTS system, separately and in combination, have remarkable potential to enhance efficiency, durability, mastery, and objective assessment of learning in a wide range of educational and training domains.

- **Perception, Image Processing and Fingerprint-Matching Expertise**
  T Ghose[1], G Erlikhman[2], P Garrigan[3], P Kellman[2], J Mnookin[4], I Dror[5], D Charlton[6] ([1]Perceptual Psychology, University of Kaiserslautern, Germany; [2]Department of Psychology, University of California, Los Angeles, CA, United States; [3]Department of Psychology, St. Joseph's University, United States; [4]School of Law, University of California, Los Angeles, CA, United States; [5]School of Psychology, University College London (UCL), United Kingdom; [6]Sussex Police, Sussex Police, United Kingdom; e-mail: tandraghose@gmail.com)

Fingerprint evidence plays an important role in forensic science. Little is known about the perceptual aspects of expert fingerprint analysis, or the differences between performances of fingerprint experts

and novices. We examined fingerprint identification performance among experts, novices, and novices with a short training intervention. Expert performance far exceeded both groups of novices. We predict the performance accuracy by using quantitative image measures borrowed from computer vision. We found that novices primarily used basic variables known to affect visual perception such as brightness and clarity of, mostly, the tenprints while the experts used domain-specific, configural features such as core and delta of the latents, ratio of areas and relative image characteristics of the latent-tenprint pair. Ultimately, it may be possible to evaluate a fingerprint comparison in terms of the quality of visual information available in order to predict likely error rates in fingerprint pair comparisons. Such a metric would have great value in both adding confidence to judgments when print comparisons are uncomplicated in terms of having high quality visual information, and it would allow appropriate caution in cases that are, from an objective standpoint of the quality of visual information, more problematic.

- **On Interactions Between Vision and Language**
  M Spivey (Cognitive and Information Sciences, University of California, Merced, CA, United States; e-mail: spivey@ucmerced.edu)

A number of studies have been showing that visual input can influence linguistic processing in real time. This tells us that the visual system can sometimes tell the language system what to do. Additional studies have been finding that linguistic input can influence visual processing in real time as well. Thus, it appears that the language system can sometimes tell the visual system what to do. The evidence points to an interactive (and decidedly non-modular) account for how perceptual and cognitive subsystems process their information. While it is clearly the case that there are brain areas that are mostly specialized for certain perceptual modalities, it is also the case that those specialized brain areas are able to process some information from outside of their specialized domain. With multiple heterogeneous perceptual subsystems sharing information back and forth in cascade, it may be that a dynamical systems approach to cognition in general, and to visual perception in particular, is required.

- **Validating a virtual head to measure the subjective cone of gaze**
  H Hecht (Psychology, Mainz University, Germany; e-mail: hecht@uni-mainz.de)

Gaze direction is an important cue that regulates social interactions. Although humans are very accurate in determining gaze directions in general, they have a surprisingly liberal criterion for the presence of mutual gaze. We first established a psychophysical task to measure the cone of gaze, which requires observers to adjust the eyes of a virtual head to the margins of the area of mutual gaze. Then we examined differences between 2D, 3D, and genuine real life gaze. Finally, the tolerance for image distortions when the virtual head is not viewed from the proper vantage point was investigated. Gaze direction was remarkably robust toward loss in detail and distortion. Important lessons for the design of eye-contact in virtual environments can be derived from these findings.

TALKS : 3D VISION, DEPTH AND STEREO

- **The role of monocular regions in the perception of stereoscopic surfaces**
  S Wardle[1], B Gillam[1], S Palmisano[2] ([1]School of Psychology, The University of New South Wales, Australia; [2]School of Psychology, University of Wollongong, Australia; e-mail: s.wardle@unsw.edu.au)

Binocular viewing of 3D scenes produces portions of the background that are only visible to one eye because of occlusion and interocular separation. Here we investigate the effect of monocular regions on perceived slant. It is well-known that horizontal stereoscopic slant is under-estimated for isolated surfaces. The addition of monocular regions significantly increases perceived slant [Gillam & Blackburn, 1998, Perception, 27, 1267-1286] however, the underlying mechanisms are unknown. Two probes equidistant from a slanted surface appear offset in depth as a result of the underestimated slant. We predicted that this bias would be reduced when monocular regions were present, as they increase perceived slant. The PSE was measured for two probes in front of slanted random-textured surfaces, with and without monocular regions. Bias was present for isolated surfaces with stereoscopic slants of +/-21 and 36 deg, with a larger bias for the latter. Surprisingly, the bias was not reduced by adding monocular regions. This contradicts the finding that monocular regions increase perceived slant and also that increasing stereoscopic slant by contrast does reduce bias [Gillam et al, 2011, Journal of Vision, 11(6):5, 1–14]. We discuss possible explanations in the context of physiological results from cells selective for depth edges.

- **The power of linear perspective in slant perception and its implication for the neural processing of orientation**

C Erkelens (Helmholtz Institute, Utrecht University, Netherlands; e-mail: c.j.erkelens@uu.nl)

Virtual slant is defined here as the slant of a surface based on the assumption of linear perspective. Virtual slants of obliquely viewed 2D figures consisting of skewed columnar grids were computed as a function of depicted slant and slant of the picture surface. Computations were based on an assumption of parallelism. Virtual slants were compared with perceived slants in binocular viewing conditions. Perceived slant was highly correlated with virtual slant. Contributions of screen-related cues, including disparity and vergence, were negligibly small. The results imply that many past findings of both transformation and (apparent) compensation in pictorial viewing are straightforwardly explained by virtual slant. Analysis shows that slant is perceived from converging lines whose angular differences are smaller than the limits that have been measured in orientation discrimination tasks. Slant perception on the basis of linear perspective implies non-local comparisons between line orientations. It suggests a yet unproposed role for the elaborate network of long-range connections between the abundance of orientation detectors in the visual cortex.

- **Shape-from-shading perception with temporally modulated shadings**

T Sato, K Hosokawa (Department of Psychology, University of Tokyo, Japan; e-mail: lsato@mail.ecc.u-tokyo.ac.jp)

Shape from shading is computationally ambiguous if lighting direction is not known. Thus, the visual system assumes that the light is coming from above. What happens if the shading is temporally modulated? The object should change its 3D-shape (convex/concave) if the light-from-above hypothesis is sturdy, but the movement of light source should be experienced if rigidity constraint is stronger. To answer this question we examined the 3D shape perception for an egg-crate stimulus with temporally modulated shading (0.5 to 8.0Hz) having either vertical or horizontal shading-gradient. For vertically graded stimuli, it was found that shape-change was dominant at 0.5 and 1 Hz but it disappeared very quickly and was almost never perceived at 2Hz. Light-source-movement almost never occurred at 0.5Hz, but it became predominant at 2Hz. It then decreased and was replaced by simple flicker beyond 3-4Hz. For horizontally graded stimuli, the shape-change almost never occurred at any temporal frequency. Light-source-movement was dominant at low temporal frequencies, and it was replace by simple flicker beyond 3Hz. These results revealed an interesting relationship between the two constraints. Rigidity generally functions at low temporal frequencies, but it is overridden by light-from-above hypothesis at frequencies below 2Hz when the stimulus was vertically graded.

- **Stereoscopic volume perception: effects of local scene arrangement across space and depth**

J M Harris (School of Psychology and Neuroscience, University of St. Andrews, United Kingdom; e-mail: jh81@st-andrews.ac.uk)

Complex three-dimensional scenes, with transparent surfaces or objects scattered through a volume, provide a compelling sensation of depth, yet can challenge models of binocular disparity extraction. Very few studies have explored the perception of volume from binocular disparity. Here we explored stereoscopic depth volume perception in scenes consisting of line elements located at a range of depths. Line elements could be scattered through a volume in depth, or presented on a pair of planes with a depth separation between them. The task was always volume discrimination: which of two volumes was the deeper in depth. We explored the effects of element density and local element layout. The perception of volume was sensitive to element density, with smaller depths being perceived for higher densities. High local disparity gradients resulted in reduced perceived volume, compared with scenes where local disparity gradients were low. The shape of the depth distribution within the volume also affected the depth of volume perceived. We explore the extent to which these perceptual effects can be explained by models of disparity extraction based on cross-correlation at a number of different spatial scales.

- **Motion in depth cued by chromatic interocular velocity differences and changing disparity**

A Wade, J Jordan, M Kaestner, P Shah (Psychology, University of York, United Kingdom; e-mail: wade@wadelab.net)

Motion towards and away from an observer generates two related but separable visual cues. The first is the temporal derivative of the retinal disparity: the rate at which the three dimensional position of the object is changing, called 'changing disparity' (CD). The other cue is the disparity of the temporal derivative of the retinal position of the object in each eye: the interocular velocity difference (IOVD). We describe a series of experiments measuring sensitivity to motion in depth using coherence thresholds

for dense random dot stereograms (RDS). We examined the effect of changing the motion in depth cue (CD vs IOVD with both decorrelated and anticorrelated dots), and the chromaticity of the individual elements (achromatic, isoluminant red/green and S-cone isolating). Isoluminant chromatic signals are generally considered to contribute very little to both motion processing and stereo depth mechanisms. Surprisingly therefore, we report that coherence thresholds for isoluminant CD and IOVD stimuli are robust and similar to those for achromatic stimuli. We hypothesize that motion in depth may engage cortical systems that do not exhibit the usual magnocellular pathway insensitivity to isoluminant color.

- **The orienting of attention across binocular disparity**
  B Caziot[1], M Rolfs[2], B Backus[3] ([1]SUNY College of Optometry, NY, United States; [2]Bernstein Center & Department of Psychology, Humboldt University Berlin, Germany; [3]Graduate Center for Vision Research, SUNY College of Optometry, NY, United States; e-mail: bcaziot@sunyopt.edu)

Attention is often described as a spotlight, which disregards depth information within the visual scene. Here we study the orienting of attention across binocular disparity, a depth cue. A discrimination target was displayed 2 degrees above fixation and—in each eye independently—displaced 20 arcmin to the right or left, resulting in 4 possible binocular locations: right, left, closer or farther than fixation. 200 ms before target onset, a small, uninformative cue was flashed either at the target location (valid cue) or at fixation (neutral cue). The cue, blank and target durations were each 100 ms, and the target was masked until response. Observers reported the orientation of the target (Gabor, 30 arcmin envelope, tilted ±30º), whose overall contrast was kept constant while pixel noise caused the Signal-to-Noise Ratio to range between 5 values (-35 to -15dB). We found a significant decrease in threshold for the valid cue at both target locations in depth and for the lateral locations. Cuing did not change vergence eye posture, measured using Nonius lines in randomly interleaved control trials. We conclude that the cue attracted attention to a specific depth plane. We currently investigate whether this cueing effect is monocular, cyclopean, or both.

TALKS : FEATURES AND OBJECTS

- **Two types of sensory comparison**
  J Mollon[1], M Danilova[2] ([1]Department of Experimental Psychology, University of Cambridge, United Kingdom; [2]Laboratory of Visual Physiology, I. P. Pavlov Institute, Russian Federation; e-mail: jm123@cam.ac.uk)

Sensory systems are largely designed to compare concurrent or consecutive inputs. Thus an edge is identified by comparing the illumination falling on adjacent retinal regions; and a given chromaticity is judged by comparison with other chromaticities in the nearby field. We suggest, however, that there exist two different types of sensory comparison, with different psychophysical properties and different neural bases. In the case of some comparisons, the precision of discrimination deteriorates rapidly as the spatial separation of the discriminanda increases. Examples are judgements of luminance or of binocular stereopsis (e.g. Marlow & Gillam, Perception, 2011). For other attributes, however, the differential threshold is constant as the targets are increasingly separated in the visual field (Danilova & Mollon, Perception, 2003). Comparisons of the first type are likely to depend on local, hard-wired comparator neurons. A paradigmatic example of such a comparator is a retinal ganglion cell with an excitatory centre and inhibitory surround. But hard-wired comparator neurons are unlikely to account for comparisons over a distance. As an alternative, we raise the possibility of a 'cerebral bus', which, like the man-made Internet, avoids the need for hard-wired connections between every transmitter and every receiver.

- **Matched objects seen closer when masked**
  E Zimmermann[1], G Fink[1], P Cavanagh[2] ([1]Institute of Neuroscience and Medicine 3, Research Centre Juelich, Germany; [2]LPP, Université Paris Descartes, France; e-mail: ec.zimmermann@fz-juelich.de)

In cases of brief gaps in visual input caused by saccade eye movements or masks the visual system must match corresponding objects from before and after the disruption. We first presented a salient visual reference and followed it with a probe date and a mask. The relative timing of the probe and mask was varied and subjects estimated the position of the probe in relation to a comparison bar that was presented later. The probe location was reported accurately when presented long before or after mask onset. However, when the probe was presented within 50 ms of the mask, the probe appeared shifted toward the reference by as much as 50 percent of their separation. This attraction effect had spatial and temporal characteristics that were similar to the compression effect seen when visual input is interrupted

by a saccade rather than a mask (Ross et al, 1997). Further tests showed that the amount of attraction was greater when object features (orientation) of anchor and probe matched. We interpret the attraction / compression effect as the result of a mechanism that computes a likely offset between corresponding objects based on the motion energy that accompanies their displacement.

- **An automatic, bottom-up process segregates homogeneous elements from similar but different elements in brief visual displays**
  G Sperling, P Sun, C E Wright, C Chubb (Department of Cognitive Sciences, University of California, Irvine, CA, United States; e-mail: sperling@uci.edu)

We are concerned with the ability of observers to selectively attend to subsets of items in complex displays. Here, displays are composed of isoluminant dots chosen from eight colors spread uniformly around the color circle. Two dots are chosen from each of 7 colors and 12 dots from the remaining color. All 14+12 dots are spatially scattered randomly on the display screen and exposed for 300 msec. When observers are required to judge the centroid (center of gravity) of only the 12 same-colored dots (ignoring the 14 other dots) in a session in which the 12-dot color is fixed across all trials, they are highly accurate. However, when each trial has a different 12-dot color, and these trials are interleaved without any pre-cue, observers are just as accurate. This indicates there is a bottom up process that recognizes and segregates homogeneous elements in a visual display, and then enables computation of properties of those segregated elements. Additionally, when instructed, observers can ignore the homogeneous dots and judge the centroid of the 7 pairs of heterogeneous dots. In other sessions, observers can attend equally to all the dots. This indicates extremely flexible top-down control of complex bottom-up perceptual processing.

- **Parallel and independent attentional facilitation of color and orientation**
  S Andersen[1], M Müller[2], S A Hillyard[3] ([1]School of Psychology, University of Aberdeen, United Kingdom; [2]Institute for Psychology, University of Leipzig, Germany; [3]Department of Neurosciences, University of California at San Diego, CA, United States; e-mail: skandersen@abdn.ac.uk)

We examined sustained attentional selection of stimuli defined by conjunctions of color and orientation. Participants attended to one out of four concurrently presented superimposed fields of randomly moving horizontal or vertical bars of red or blue color in order to detect brief intervals of coherent motion. Stimulus processing in early visual cortex was assessed by recordings of steady-state visual evoked potentials (SSVEPs) elicited by the flickering stimuli. Attentional selection of conjunction stimuli was found to be achieved by parallel enhancement of the two defining features. This finding was confirmed and extended in a second experiment, in which we directly contrasted selection of single features and feature-conjunctions. We found that conditions in which selection was based on color or orientation only exactly predicted the magnitude of attentional enhancement when attending to a conjunction of both features. Furthermore, enhanced SSVEP amplitudes of attended stimuli were accompanied by equal sized reductions of SSVEP amplitudes of unattended stimuli in all cases. In conclusion, attentional modulation of stimulus processing in early visual cortex could be fully explained by parallel and independent facilitation of both feature dimensions.

- **Human feature-based attention comprises two spatio-temporally distinct processes**
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Feature-based attention (FBA) represents the orienting of attention towards a specific stimulus feature and facilitates its processing throughout the visual field. Current hypotheses on the neuronal mechanisms underlying FBA include the feature-similarity gain model by which FBA selectively enhances the response of neurons representing specific feature attributes (as e.g. 'red' or 'moving upward'), and the dimensional weighting account, which proposes attention-dependent weighting of the task-relevant dimension (e.g. colour or motion). Both hypotheses have gained experimental support, but they contradict each other regarding the representation of non-attended feature attributes within the attended feature dimension. We investigated this issue by recording event-related potentials (ERPs) during performance of a complex delayed-match-to-sample task. Our findings clearly indicate that in the human brain, FBA in fact consists of two processes, one specific for the feature attribute, and another one specific for its dimension. ERPs of both FBA processes showed spatially independent attentional

modulations particularly about 150 – 200 ms following stimulus onset and were characterized by distinct spatiotemporal activation patterns. Dimension-specific effects first emerged over frontal electrodes and then spreaded towards parieto-occipital electrodes. Attribute-specific effects developed on top of these dimension-specific effects, but were restricted to parieto-occipital electrodes.

- **Multidimensional visual discrimination by pigeons**
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To how many visual dimensions can organisms simultaneously attend? To find out, we trained pigeons (Columba livia) on a go/no go discrimination to peck only 1 of 16 visual stimuli created from all possible combinations of four binary dimensions: brightness (dim/bright), size (large/small), line orientation (vertical/horizontal), and shape (circle/square). Half of the pigeons had SSVL (square, small, vertical, light gray) as the rewarded stimulus (S+) and the other half had CLHD (circle, large, horizontal, dark gray) as the rewarded stimulus (S+). We recorded pecking during the 15 s that each stimulus was presented on each training trial. Training continued until pigeons responded to all 15 nonrewarded stimuli (S-s) at rates less than 15% to the S+. All pigeons acquired the discrimination, suggesting that they attended to all four dimensions of the multidimensional stimuli. Learning rate was similar for all four dimensions. The more dimensions along which the S-s differed from the S-, the faster was discrimination learning, suggesting an additive benefit from increasing perceptual disparities of the S-s from the S+. Many pigeons showed strong signs of attentional tradeoffs among the four dimensions during discrimination learning. Our new discrimination learning procedure shows considerable promise for studying selective attention in animals.

TALKS : ILLUSIONS

- **Dentists make larger-than-necessary holes in teeth if the teeth present a visual illusion of size**
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There is very little prospective evidence that illusions can influence health-care treatment; we sought such evidence. We simulated treatment using dentistry as a model system. We supplied eight, practicing, specialist dentists with at least 21 isolated teeth, randomly sampled from a much larger sample of teeth they were likely to encounter. Teeth contained holes and we asked the dentists to cut cavities in preparation for filling. Each tooth presented a more or less potent version of a visual illusion of size, the Delboeuf illusion, that made the holes appear smaller than they were. Dentists and the persons measuring the cavities were blind to the parameters of the illusion. Cavity size was linearly related to the potency of the Delboeuf illusion ($p < .01$). When the illusion made the holes appear smaller, the dentists made cavities larger than needed. We conclude that the visual context in which treatment takes place can influence the treatment. Undesirable effects of visual illusions could be counteracted by a health practitioner's being aware of them and by using measurement.

- **Seeing around the corner: Occluded objects can be experienced as directly visible**
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We present a thought-provoking visual illusion in which portions of a scene are experienced as being both directly visible and occluded at the same time. In our experiments, subjects viewed an opaque disk with an open sector rotating in front of a background and indicated a) the perceived angular extent of the occluding disk sector and b) the perceived angular extent of the part of the background experienced as directly visible. In both cases, a static sector of adjustable angle was used for matching. While the perceived angular extent of the occluding disk sector corresponded to the physical extent of the stimulus, the perceived angular extent of the background region experienced as directly visible through the open sector in the occluder was clearly overestimated. Thus, the sectors of the circle experienced as directly visible and occluded sum to more than 360 degrees, which –like Escher's well-known paintings – makes the total percept an "impossible figure". To explain this seemingly paradoxical observation, we argue that the conscious experience of direct visibility is not a mental representation of physical visibility,

but rather a representation of reliable sensory evidence: Functionally, this might be more useful than estimates about actual visibility.

- **The whole of a face is more than the sum of its parts: direct evidence from frequency-tagging of a composite face**
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The face is often considered as the quintessential whole, or Gestalt. This is illustrated by the composite face illusion, in which the top and bottom halves of two faces fuse to form a perceived novel face. Objective evidence that the whole of a face is more than the sum of its parts is still lacking. Here we contrast-modulated the top and bottom halves of a composite face with different flicker frequencies (f1: 5.87 Hz; f2: 7.14 Hz) while recording scalp electroencephalogram (EEG) in 15 observers. A face was presented during 70 sec while they fixated the top face half. Thanks to this frequency-tagging approach, we distinguished objectively the responses to the simultaneously presented top and bottom face halves. Most importantly, we observed intermodulation components (IMs: f1-f2: 1.26 Hz; f1+f2= 13.01 Hz) over the right occipito-temporal hemisphere, reflecting the nonlinear interaction of the frequencies. While the fundamental frequencies response remained unchanged following inversion and spatial misalignment of face parts, the IM components decreased substantially in these conditions. These observations constitute an objective trace of a unified face representation in the human brain, demonstrating that the whole of a face is more than the sum of its parts.

- **A novel visual illusion reveals different principles for perception and action**
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The visual perception of biological motion has been suggested to have a tight coupling with the movement generation process. A well-known example is the speed illusion of single dot movements – the apparent fluctuation in the speed of a dot which is actually moving uniformly along a curved path. It has been suggested that the motion appears uniform only if it resembles the natural drawing motion of human subjects: For elliptic figures, this is known as the one-third power-law relationship between the speed and the radius of curvature ($v(t)$ $r(t)^{1/3}$) (Viviani and Stucchi 1992). However, the phenomenon has not been rigorously studied for non-elliptic movements. Our optimal-control based theory predicts a whole family of power-law relationships depending on the shape of the movement paths, instead of the fixed 1/3 power-law. Such generalized relationship was indeed confirmed in our movement and perception experiments – smaller exponent is observed for a path shape whose curvature oscillates with higher frequency. The data, however, revealed different ranges of exponents for two tasks. In the motor task, the exponent was found to range between 0 and 2/3, while it was between 0 and 1/2 in the perception task, which can be predicted from optimizing two different cost functions. Therefore, our result reveals two similar yet different principles for the perception and the action processes of curved motion.

- **An illusory distortion of moving form driven by motion deblurring**
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Many visual processes integrate information over time – temporal integration. One consequence is that retinal motion can generate blurred form signals, similar to motion blur captured in photography at slow shutter speeds. Subjectively, retinal motion blur tends to be invisible. One suggestion is this ensues because humans can't distinguish focused from blurred moving form. We noticed a novel illusion that seems to challenge this view. The apparent shape of circular moving objects can seem distorted when their rear edges lag leading edges by 60ms, with a portion of rear extremities suppressed from awareness. We also found that sensitivity for detecting blur, and for discriminating between blur intensities, is uniformly worse for physical blurs behind moving objects, as opposed to in-front. These 'dipper' functions are consistent with blur having to reach a threshold intensity for detection, and with this threshold being greater for signals trailing behind moving contours. This, and our novel illusory distortion of moving form, could ensue from the biphasic temporal impulse response function, with a suppressive phase 60ms after stimulus onset. Accordingly, form signals behind moving contours would be subject to a time dependent suppression, bringing about deblurring and, in some circumstances, an illusory distortion of moving form.

◆ **The New Moon Illusion**

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In the traditional moon illusion, the moon appears to be larger when it is near the horizon compared to overhead. Our New Moon illusion can be seen when both sun and moon are visible and is most striking when the sun is setting and the moon is higher in the sky. Under these conditions, the sun does not appear to be in a direction perpendicular to the backward tilt of the terminator (boundary between the lit and dark side of the moon) as must be the case from physics and can be verified by holding up a piece of string to 'join' the sun and the moon. There is a cognitive aspect to the illusion, arising from the incorrect assumption that because the terminator is tilted backwards, the sun must be higher in the sky. There is also a perceptual aspect that Walker (1975, The Flying Circus of Physics, Wiley) has attributed to our perception of the sky as a spherical dome. While this may be part of the explanation, it raises the deeper question of how we judge which lines in the world are straight and parallel (Helmholtz H. von, 1910 Physiological Optics; Rogers and Rogers, Perception 38, 2009).

TALKS : DEVELOPMENT AND AGEING

◆ **The two key parameters of evolution**

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David Marr (Marr, 1982, Vision: A computational investigation into the human representation and processing of visual information, New York, Freeman) urged neuroscientists to consider the computational theory underlying visual processes but this has rarely been attempted for vision as a whole. From an evolutionary or developmental perspective, two important things change as organisms develop more complex behaviours: (i) the dimensionality of the space describing sensory+motivational contexts for action and (ii) the length of the path through that space before a reward is achieved. For example, the behaviour of a single-celled organism could be described using only two stored contexts defined in a three-dimensional space (signalling, say, the concentration gradients of two chemicals in the environment and the mass of the organism) while the equivalent sensory+motivational contexts for a human might be 10^{10} in length with a concomitantly larger number of stored contexts. The analysis of retinal flow, visual stability, multi-sensory integration and other processes can be viewed quite differently in this framework. The output of the cortex is a point that moves through a high dimensional space. This truism may be a helpful concept if the paths it follows through the space are shaped by evolution and development.

◆ **Development of BOLD response to visual motion in infants**

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Development of vision in infants has been studied with dense ERPs, demonstrating differential maturation of cortical areas (Braddick et al, 2003), but there has been no direct measurements of the maturation of individual cortical areas in new-borns by imaging methods. We measure BOLD responses to visual stimuli in 10 cooperative infants of 7 weeks old and studied the development of the various cortical responses to flow versus random motion. The results show that at 7 weeks of age the major circuits mediating the response to flow motion are already operative, with stronger response to coherent flow spiral motion than to random speed-matched motion (Morrone et al 2000) in parietal-occipital area (presumed MT+), pre-cuneous, posterior parietal (V6) areas and an area corresponding anatomical to PIVC, which in adults receives visual-vestibular input (Cardin & Smith et al 2010). As in adults, V1 does not respond preferentially to coherent motion. Resting-state connectivity maps collected in 5 infants indicate weak connectivity between V1 and the parietal-occipital regions selective for flow motion, suggesting the existence of an alternative input that bypasses V1. In conclusion, the results revealed an unexpected maturation of the motion analysis circuit of the associative area, probably not mediated by striate cortex.

◆ **A neural marker of perceptual consciousness in infants**

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Studying the neural basis of consciousness has been made possible in adults by mapping subjective reports to their neurophysiological underpinning. However, studying this issue in infants remains challenging because they cannot report about their own thoughts. How, then, might one test whether the brain mechanisms for conscious access are already present in infancy? Here, to circumvent this problem, we studied whether an electrophysiological signature of consciousness found in adults, corresponding to a late non-linear cortical response to brief pictures, already exists in infants. We recorded event-related potentials (ERPs) while 5, 12 and 15 month-old infants viewed masked faces at various levels of visibility. In all age groups, we found a late slow wave showing a non-linear profile at the expected perceptual thresholds. However, this late component shifted from a weak and delayed response in 5-month-olds to a sustained and earlier response in older infants. These results reveal that the brain mechanisms underlying conscious perception are already present in infancy, but undergo a slow acceleration during development. Relevant publication: Kouider, S., Stahlhut, C., Gelskov, S., Barbosa, L, de Gardelle, V., Dutat, M., Dehaene, S., & Dehaene-Lambertz, G. A neural marker of perceptual consciousness in infants. Science, manuscript in press.

◆ **The development of categorical colour constancy**

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Colour naming and colour constancy serve the purpose of reliably identifying surface colours across illuminations and observers. To test for common developmental origins, we investigated whether categorical colour constancy interacts with category development during colour term acquisition. For this purpose, we focused on toddlers who are just developing linguistic colour categories (39-42 months). We let them categorise 160 Munsell chips and identify the category prototypes under different illuminations. We disentangled illumination-specific changes in categorisation from unspecific variations. Results showed that categorical consistency was reduced due to illuminant-specific changes. Moreover, the changes in category membership were partly in line with those predicted by the change in illumination. These illumination-specific changes of category membership were correlated to category maturity, which is the similarity of a toddler's categories to adult ones. In contrast, colour constancy of category prototypes was not correlated to category maturity, mainly because toddlers tended to overcompensate for illumination changes when selecting prototypes. Overall, these results suggest that category development involves adaptation to illuminant changes, and interacts with high-level, probably cognitive, determinants of colour constancy.

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◆ **Developmental dissociation of analytical and holistic object recognition in adolescence**

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Previous research (e.g., Jüttner et al, 2013, Developmental Psychology, 49, 161-176) has shown that object recognition may develop well into late childhood and adolescence. The present study extends that research and reveals novel differences in holistic and analytic recognition performance in 7-11 year olds compared to that seen in adults. We interpret our data within Hummel's hybrid model of object recognition (Hummel, 2001, Visual Cognition, 8, 489-517) that proposes two parallel routes for recognition (analytic vs. holistic) modulated by attention. Using a repetition-priming paradigm, we found in Experiment 1 that children showed no holistic priming, but only analytic priming. Given that holistic priming might be thought to be more 'primitive', we confirmed in Experiment 2 that our surprising finding was not because children's analytic recognition was merely a result of name repetition. Our results suggest a developmental primacy of analytic object recognition. By contrast, holistic object recognition skills appear to emerge with a much more protracted trajectory extending into late adolescence.

◆ **Capturing light and age-related changes in spatial vision**
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Capturing vision changes at low light levels can help separate the effects of normal aging of the retina and visual pathways from early stage disease. The limits of normal, age-related changes in monocular and binocular functional contrast sensitivity were measured from photopic to mesopic light levels. 95 participants, age 20 to 85 years were examined. Measurements of contrast sensitivity were made using a four-alternative, forced-choice procedure at the fovea (0°) and parafovea (±4°), along the horizontal meridian. Pupil size was measured continuously for screen luminances 34-0.12cd/m2. The Health of the Retina index (HRindex) was computed to capture the rate of decline in contrast sensitivity with decreasing light level. Participants were excluded if they exhibited signs of ocular disease, or performance outside normal limits for interocular differences or HRindex values. The HRindex showed greater decline and correlation with age at the parafovea (r2=-0.34) than the fovea (r2=-0.19), consistent with histological findings of rod loss and its link to age-related degenerative disease. 23% of clinically normal participants had HRindex values outside normal limits. Binocular summation of contrast signals declined with age, independently of interocular differences. The HRindex, interocular differences and binocular summation can be used to detect early-stage, sub-clinical disease.

TALKS : MOTION PERCEPTION

◆ **The size of antagonistic centre-surround motion mechanisms decreases with increasing spatial frequency**
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Human ability to discriminate motion direction of a Gabor patch diminishes with increasing size and contrast. This result has been explained by center-surround antagonism in motion sensors. We are interested in the size of motion sensors tuned to different spatial frequencies. Using Bayesian staircases, we measured duration thresholds of 5 subjects in a motion-direction discrimination task using vertically oriented gratings moving at 2 deg/sec, and presented with high contrast (46%) in the centre of the screen. We tested three spatial frequencies, 1 c/deg, 3 c/deg, and 5 c/deg, and six Butterworth-window diameters within the range 0.2 to 12 deg (depending on the spatial frequency). At each spatial frequency, duration thresholds increase with increasing size and stabilize when the size of the spatial window reaches a certain size. The size at which the duration thresholds stabilize gives an indication of the diameter of the suppressive surround. This diameter decreases approximately from 10 to 3 deg with increasing spatial frequency. These sizes are similar to the receptive-field sizes (at 0 deg retinal eccentricity) of neurons in the visual area MT.
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◆ **Cortical Correlates of Motion Surround Suppression in Area MT**
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As the size of a high contrast moving pattern increases, it becomes harder to perceive its direction of motion (Tadin et al. 2003). This counter-intuitive effect, termed as “spatial suppression” was suggested to be a consequence of the center-surround antagonism in the cortical area MT. Here, using fMRI, we study the behavioral and neural processes underlying this mechanism, and investigate the role of attention. Five participants participated in the study. In the behavioral experiments, duration thresholds were assessed for detecting the direction of drifting Gabor patches in different sizes, contrasts and frequencies. Duration thresholds increased significantly as the size of the stimulus increased for high contrast (65%) but not for low contrast (2%) patches. In the fMRI experiments BOLD signals were recorded while observers viewed drifting Gabor patches in different contrasts and sizes. When observers performed a demanding fixation task, cortical activity in MT increased with increasing size for low contrast patches, and decreased for high contrast patches. When observers did not perform the attention task BOLD signal did not vary with size for high contrast patches, but increased for low contrast patches. These results are in line with the proposed role of MT in spatial suppression.

- **Different perceptual decoding architectures for the central and peripheral vision revealed by dichoptic motion stimuli**

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V1 encodes both the summation of visual inputs to the two eyes and the difference between these inputs (Li and Atick, 1994, Network,5(2),157-174). However, perception favours the sum. If flashing gratings cos(kx+p)cos(ft+q) and sin(kx+p)sin(ft+q) are shown to the left and right eyes respectively, (x: space; t: time; k: spatial frequency; f: temporal frequency), binocular summation and difference each contains a drifting grating, but with opposite drift directions. The summation rather than the difference direction is more likely perceived with a brief (e.g., 0.5 second) foveal viewing of this dichoptic stimulus (Shadlen and Carney, 1986, Science,232(4746),95-97). I found this bias for binocular summation to be absent with peripheral viewing (about 10 degree eccentricity; stimulus enlarged to counter acuity change). Furthermore, reducing the drifting speed (by decreasing f from 5 Hz to 2.5 Hz), likely facilitating top-down visual feature tracking, increased this bias in central, but not peripheral, vision. Since higher visual areas critical for recognition are devoted to central vision, I suggest that the summation bias arises because top-down feedback generative signals, which enjoy binocular correlations based on visual input statistics, are involved in foveal analysis (recognition) by synthesis, but that these signals are weaker or unavailable in the periphery.

- **Representation of global motion in higher visual areas**

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Neuroimaging studies suggest that hMT+ has a role in extracting global motion. However, the role of higher motion-sensitive areas is less clear. We used 3T fMRI and MVPA to test for global motion sensitivity in several motion-processing regions. A novel RDK stimulus was developed in which translational global motion along either of two orthogonal axes could be created using the same set of local motions in both cases. Each dot moved back and forth (reversing direction at 1Hz) along a fixed axis of motion that was assigned randomly. All dots reversed synchronously. In one variant, temporal phases (0 or 180) were assigned so as to produce global translation alternating between 45 and 225deg (the average local direction). In the other, they were assigned such as to produce global motion along the 135-315 axis. Because the local dot motions are the same, differing only in the temporal phase of dot direction reversal, successful decoding of the two stimuli indicates global-motion sensitivity. The results revealed sensitivity in hMT+ but not V1, as expected. However, the best performance was in VIP, CSv, and V6. This suggests that the representation of global motion may first emerge in MT+ then strengthen in higher-level visual regions.

- **Slow eye movements reflect human decision-making about visual motion direction**

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The random-dot-motion (RDM) task, which tests motion signal detection in noise, has proved extremely useful in the study of sensory decision-making. Neuronal recordings in monkeys have revealed how motion-direction information is accumulated between stimulus onset and a monkey's decision. However, a non-invasive and easily-measured variable that reflects the dynamics of decision-making in humans at a fine temporal scale remains to be found. Here, we evaluate whether slow eye movements (SEMs) in humans viewing a RDM pattern are correlated with their ongoing decision-making process, inspired by the known parallels between motion perception and SEMs (like smooth pursuit). Human subjects viewed a low-coherence RDM pattern moving in one of two directions and indicated their decision about motion direction using either a keyboard press or a saccade. Independent of response modality, their eyes slowly moved ("drifted") in the direction of the impending decision. Trials with SEMs were associated with better performance and greater confidence in judgment. SEMs showed a pattern similar to that of the neural activity of single neurons in monkey parietal cortex reported in the literature. SEMs may thus provide a window into decision-making and allow the testing of motion-processing models with high temporal resolution.

- **The effect of adaptive camouflage on perceived speed in neutral and stressful situations**
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Static high contrast colouration – "dazzle camouflage" - can reduce perceived speed by around 7% (Scott-Samuel et al., 2011, PLoS ONE, 6(6):e20233). We investigated the effect of moving dazzle patterns on the perceived speed of a target that was itself moving. A drifting 100% contrast vertical sinusoidal grating increased perceived speed when moving in the same direction as the object it covered, and reduced apparent speed when moving against the object direction. This effect was largest (15% speed change) when the grating and object speeds matched, and persisted when: stimulus contrast was reduced to 6.25%; the area covered by the moving texture was reduced to 25% of the object's surface (divided equally between the leading and trailing edges); the moving grating was replaced by a zigzag pattern; subjects inhaled 7.5% CO2-enriched air, a procedure known to induce anxiety. These data offer the intriguing prospect of multi-purpose camouflage: if dazzle colouration need not be high contrast, completely covering an object, or of a particular pattern, then it could be static and cryptic for a stationary object, yet also dynamic and speed distorting when the object moves. Furthermore, the stress manipulation suggests that our laboratory results may obtain in more realistic situations.

TALKS : NEW APPROACHES TO METHODS IN VISION RESEARCH

- **Repetition priming of perceptual transitions: an empirical test of the "free-energy principle"**
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The visual system relies on prior knowledge to resolve perceptual uncertainty. According to the "free energy principle" [Friston, 2010, Nature Reviews Neuroscience, 11(2), 127–38], these priors are adjusted dynamically to reflect recent visual experience. Importantly, the relevant experience is predicted to include both perceptual states and transitions. For the first time, we demonstrate here priming of transitions independently of states. Structure-from-motion was produced by planar flow of dots. Inversion of flow created an ambiguity as to how this physical event was perceptually resolved: as reversal of apparent motion (perceptual transition), or as constant rotation (no perceptual transition). Inter-trial correlations demonstrated facilitatory priming: past trial outcomes facilitating the same outcome on future trials. However, the results were equally compatible with states (clockwise or counter-clockwise rotation) priming states and with transitions (reversed or stable rotation) priming transitions. To distinguish these alternatives, we controlled the direction of rotation, obtaining negative correlations between states. Nevertheless, positive correlation between transitions remained comparably strong, demonstrating specific priming of transitions. Our findings show for the first time that perceptual transitions induce a specific memory trace, which facilitates future transitions independently of other memory traces induced by perceptual states, confirming a key prediction of the "free-energy principle".

- **A classification-image-like method reveals observers' strategies in two-alternative forced choice tasks**
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There is still uncertainty about how observers perform even the simplest tasks, such as making 2AFC decisions. We demonstrate a novel method of using classification images to calculate "proxy decision variables" that estimate an observer's decision variables on individual trials, which provides a new way of investigating observers' decision strategies. We tested three models of the mapping from decision variables to responses. METHOD. Observers viewed two disks in Gaussian noise, to the left and right of fixation, and judged which had a contrast increment. For each trial we calculated the cross-correlation of the classification image with the two disks, providing a proxy decision variable for each alternative. After several thousand trials we mapped the observer's decision space: we plotted the probability of choosing the right-hand disk as a function of the two decision variables. We tested the hypotheses that observers base their decisions on (a) the difference between the two decision variables, (b) independent yes-no decisions on the two decision variables, or (c) just one of the decision variables. RESULTS. Decision space maps showed that observers use the difference between the decision variables. We conclude that the difference model favoured by detection theory is a valid model of 2AFC decisions.

- **A bias-free measure of Retinotopic Tilt Adaptation**
  M Morgan (Visual Perception Group, Max-Planck-Institute Neurological Research, Germany; e-mail: michael.morgan@nf.mpg.de)

The traditional Method of Single Stimuli (MSS) for measuring perceptual illusions and context effects confounds perceptual effects with changes in the observer's decision criterion. By deciding consciously or unconsciously to select one of the two response alternatives more than the other when unsure of the correct response, the observer can shift their psychometric function in a manner indistinguishable from a genuine perceptual shift. This talk describes a novel spatial two-alternative forced-choice method to measure a perceptual aftereffect in a bias-free manner by its influence on the shape of the psychometric function rather than the mean. The method was tested by measuring the effect of motion adaptation on the apparent Vernier offset of stationary Gabor patterns. The shift due to adaptation was found to be comparable in size to the internal noise, estimated from the slope of the psychometric function. By moving the eyes between adaptation and test we determined that the adaptation is retinotopic rather than spatiotopic.

- **Evolving the stimulus to fit the brain: Investigating visual search in complex environments using genetic algorithms**
  E Van der Burg[1], J Cass[2], J Theeuwes[3], D Alais[1] ([1]School of Psychology, University of Sydney, Australia; [2]Psychology, University of Western Sydney, Australia; [3]Cognitive Psychology, VU University, Netherlands; e-mail: erik.vanderburg@sydney.edu.au)

Using a visual search display too complex to be tractable with conventional methods, we applied a genetic algorithm to investigate how observers search within complex visual environments. Starting with a population of random displays (136 distractors per display, varying in colour and orientation), the genetic algorithm mimics natural selection by combining over successive generations displays affording fastest search (the 'fittest') and discarding all others. For all observers, displays affording efficient search evolved very rapidly. From first-generation search times of 5 s, search times declined rapidly over just 14 generations. Interestingly, all observers evolved similar displays even though the search space was large and the evolution unconstrained. Specifically, colour evolved first, followed by orientation. This pattern was not predicted by current models of visual search. The genetic algorithm, therefore permits highly efficient search of multidimensional spaces and produces consistent evolution patterns that point to the brain's own search strategies and preferred saliency cues. This a-theoretical approach provides unique insights into complex visual search and is adaptable to a wide range of paradigms which, until now, have been intractable using traditional methods.

- **Classification of equiluminant color gratings in the human visual cortex with multi-voxel pattern analysis: A color space-free approach**
  O F Gulban, A I Isik, H Boyaci (Dept. of Psychology & Nat. MR Research Center, Bilkent University, Turkey; e-mail: farukgulban@gmail.com)

While the early stages of color processing is well understood, how color perception is achieved in the cortex still remains unknown. In order to investigate the spatial organization of color tuned neurons in the cortex, we conducted an fMRI experiment and used Multi Voxel Pattern Analysis (MVPA) technique to analyze the data. Our main purpose was to test whether color information in the cortex can be decoded successfully using MVPA methods. In previous studies that explored this hypothesis (Brouwer & Heeger, 2009) researchers used colors from standard color spaces assuming perceptual equiluminance, and used specific hues instead of color-opponent stimuli. In the present study, we first conducted a psyhophysical experiment in order to obtain isoluminant colors per participant to use in the fMRI experiment. Then, we presented isoluminent red-green and blue-yellow grating patterns in a block design paradigm with a demanding attention task. GLM results and event related averaging showed no difference between the mean BOLD responses for the stimuli across all the runs. Within functional regions of interest that correspond to the visual position of the colored stimuli, successful classification results were observed across participants. We conclude that it is possible to classify color-opponency information in the occipital cortex.

◆ **Contrast sensitivity deficits in amblyopia**

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Loss of contrast sensitivity is one of the core deficits in amblyopia. Here we examined the patterns of contrast sensitivity deficits in anisometropic amblyopia, strabismic amblyopia, and strabismus without amblyopia. For subjects with these visual impairments, and a normal cohort, we measured three contrast sensitivity functions (CSFs): two monocular and one binocular. Measurement of three CSFs over a relatively short testing time (10-15 min) was enabled by the quick CSF method (Lesmes et al, 2010). Our results showed that the high frequency cutoff of the CSF was highly correlated with conventional logMAR acuity, for all conditions. Consistent with previous findings, contrast sensitivity was significantly reduced in the amblyopic eye. Neither amblyopic group showed evidence of binocular summation: binocular and better-eye CSFs were the same. Strabismics without amblyopia also showed no binocular summation, and did not show differences in sensitivity between eyes. Furthermore, a principal components analysis classifier showed that the CSF of the worse eye and the difference between eyes explain most of the variance in these diverse subjects. We conclude that monocular and binocular CSF deficits are defining characteristics of amblyopia. Our results further demonstrate that the quick CSF provides an efficient assessment tool for vision research.

POSTERS : ATTENTION

◆ **Parallel processing under conditions of discomfort glare**

1 G Bargary, J L Barbur (Applied Vision Research Centre, City University London, United Kingdom; e-mail: gary.bargary.1@city.ac.uk)

A light source causes scattered light on the retina and this in turn reduces object contrast and can also cause discomfort glare. Previous work addressing the effect of glare on vision has focused mainly on the reduction of object contrast caused by light scatter, rather than the often-accompanying discomfort glare. This study compares performance measured with single and multiple stimuli under varying levels of glare. This reveals the cost of parallel processing, but any additional cost in performance across glare levels can be attributable to discomfort glare. Standard contrast-acuity tasks (containing single and multiple stimuli) were carried out with and without an annulus LED glare source. Discomfort glare thresholds were determined prior to testing. All contrast-acuity tasks were carried out in the absence of glare. The tests were then repeated with the glare source set at the subject's discomfort glare threshold and 0.3 log units above and below this threshold. Parallel processing with multiple stimuli causes increased thresholds when compared to single stimuli. This expected cost was however significantly greater at and above the discomfort glare threshold. Studies that have focused solely on disability glare may be underestimating the adverse effect glaring light sources can have on visual performance.

◆ **Visual segmentation of spatially overlapping subsets**

2 I Utochkin (Cognitive Research Laboratory, The Higher School of Economics, Russian Federation; e-mail: isutochkin@inbox.ru)

In everyday perception we often see multiple objects forming heterogeneous spatially overlapping subsets (such as berries and leaves on a bush) and are able to distinguish between these subsets. In three experiments I studied the limitations of this subset segmentation ability and the role of attention in this process. Observers had to enumerate the number of briefly flashing spatially-overlapped color subsets of 6, 12, or 36 dots (1 to 6 colors in total). In all experiments, 1 or 2 subsets were enumerated with almost same speed and accuracy, while all other numbers yielded substantial increment in error rate and reaction time. This indicates that 2 subsets can be segmented in parallel, and once this limit is exceeded serial shifts of attention are required for segmentation. I also found that segmentation benefits from large sets and this doesn't depend on spatial arrangement of items in the visual field (Experiment 2).This provides evidence in favor of parallel collecting abstract statistics within each subset that eventually makes subset representations more discriminable. Finally, the evidence was found that observers are able to use an "all-colors" internal template when possible that helps in segmentation when large numbers of subsets are presented (Experiment 3).

◆ **Spatial distribution of attention in three dimensional space**

3 Y Seya, M Yamaguchi, H Shinoda (Ritsumeikan University, Japan; e-mail: yseya@fc.ritsumei.ac.jp)

To investigate the spatial distribution of attention in three dimensional space defined by binocular disparity, we used a useful field of view task that has been proved useful to reveal attentional resources and spatial distribution of attention. Participants localized a target presented in the peripheral visual field (peripheral target) while identifying a character presented in the fovea (central target). We manipulated the depth of the peripheral target (Experiments 1 and 2) or the central target (Experiment 3). The results of Experiments 1 and 2 revealed no difference in the peripheral task performance by the depth of the peripheral target. However, Experiment 3 showed that the peripheral task performance was lower when the peripheral target was presented on different depths relative to the central target than when it was presented on the same depth. The performance was also lower when the peripheral target appeared on a depth in front of the central target than behind it. The results of Experiment 3 suggest that attention can be spread in three dimensional space.

◆ **Space-based Attention and Visual Awareness in Inattentional Blindness Task**

4 M Kuvaldina, P Iamshchinina (Department of Psychology, St.Petersburg State University, Russian Federation; e-mail: kuvaldinamara@gmail.com)

Inattentional blindness (IB) is the inability to notice a salient item while attention is engaged in some other task [Simons, Chabris, 1999, Perception, 28, 1059–1074]. It has been argued that IB effect includes either attention or awareness modulations. To test this we modified a procedure of M. Koivisto [Koivisto, Kainulainen, Revonsuo, 2009, Neuropsychologia, 47, 2891–2899] which allowed to discriminate visual awareness negativity (VAN) and selective attention negativity (SN) and thus to investigate the effect of IB on both electrophysiological correlates. In ERP study subjects were presented with pairs of masked or unmasked Latin letters. The task was to report on the target presence or absence while the subject attended either right or left visual field. When the unmasked target presented in the unattended visual field was missed by the subject, we considered it to be the IB condition. In accordance with Koivisto's results, VAN was observed earlier than SN. VAN was present in both attention conditions suggesting that it is independent from attention shifts. Comparison of IB condition with non-target condition showed posterior negative amplitude shift (VAN) but showed no SN. We conclude that in this task IB is sensitive to awareness modulation but not to attention modulation.

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◆ **Individual differences in the attentional blink: The temporal profile of large versus small blinkers**

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When two targets are presented in close temporal succession, the majority of people frequently fail to report the second target. This 'attentional blink' (AB) is informative about the rate at which stimuli can be perceived consciously and is generally considered to reflect a fundamental restriction in selective attention. However, as previously demonstrated, there are strong individual differences in the magnitude of the AB. In the current study, we directly tested the properties of temporal selection by analysing response errors, allowing us to uncover individual differences in suppression, delay, and diffusion of selective attention across time. In addition, we determined whether the individual ability to avoid an AB comes at a cost of temporal order information. We found that the largest blinkers showed only a modest amount of suppression during the AB. Individuals with a small AB showed no suppression, were more precise in selecting the second target, and made fewer order reversals. However, when the second target immediately followed the first target (at lag 1), the latter group made relatively more response errors and showed a selection delay; possibly a consequence of a relatively faster and more precise target selection process.

◆ **Training and the Attentional Blink: Limits Overcome or Expectations Raised?**

6 M Tang, D Badcock, T Visser (School of Psychology, University of Western Australia, Australia; e-mail: matthew.tang@uwa.edu.au)

The attentional blink (AB) refers to a deficit in reporting the second of two sequentially presented targets when separated by less than 500 ms. Two decades of research suggest the AB is a robust phenomenon

that is likely attributable to structural or capacity limits in visual processing. This assumption, however, has recently been undermined by a demonstration that the AB could be eliminated after only a few hundred training trials [Choi, Chang, Shibata, Sasaki and Watanabe, 2012, Proceedings of the National Academy of Sciences of the United States of America, 109(30), 12242-12247]. The present work examined whether training benefited performance directly by eliminating processing limitations as claimed or indirectly by creating expectations about when targets would appear. Consistent with the latter option, when temporal expectations were eliminated training did not eliminate the AB. These results suggest that while training may ameliorate the AB indirectly, processing limits evidenced in the AB cannot be eliminated simply by repeated exposure to the task.

◆ **Phonologic, morphological, semantic and lexical connections between Chinese characters modulate attentional blink**

7 H Cao, H Yan (University of Electronic Sciences and Technol, China;
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Human observers possess the remarkable ability to report a visual target even when it is embedded in a rapid serial visual presentation (RSVP) stream of spatially overlapping distractors. However, when two such targets must be reported (conventionally, T1 and T2), report of T2 is severely impaired if it is presented within approximately 500 ms of T1. This transient deficit is known as the attentional blink (AB; Raymond et al., 1992). A number of studies provided evidences that the magnitude of the AB effect can be modulated by manipulating the allocation of attentional resources to the T1 or T2. But little experiments were conducted with Chinese characters and words. As we know, there are complicated connections between Chinese characters. Therefore, Chinese characters are good cases to study the relationship of T1 and T2. At issue in the present work was how phonologic, morphological, semantic and lexical connections between Chinese characters modulate AB effect. Our results showed that strong AB was investigated when T1 and T2 were irrelative Chinese characters. However, gradual attenuation of the AB was observed with two phonologic, morphological and semantic Chinese characters. No AB effect was found any more when T1 and T2 were two lexical words.

◆ **Target and mask preview effects in object substitution masking**

8 M Pilling (Psychology, Oxford Brookes University, United Kingdom;
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Object substitution masking (OSM) is a form of masking in which a briefly presented target present in a stimulus array is rendered imperceptible by a sparse mask -typically consisting of just four surrounding dots which trail the offset of the target. Recent accounts suggest that OSM occurs when the visual system fails to individuate target and mask at the object token level of description. Previous studies have indicated that OSM is reduced, or even eliminated, when a preview is given of the target or mask elements before onset of the stimulus array. Here target and mask preview are compared directly and found to have largely symmetrical effects, consistent with the object token explanation. However, curiously, OSM is not entirely eliminated even with a 650 ms preview of target or mask elements. Interestingly, the amount of unmasking arising from target/mask preview was essentially the same irrespective of stimulus array size –varied between 4 and 12 items. This finding indicates that the visual system has a high capacity to represent object token elements exceeding at least 12 items.

◆ **A unified system-level model of visual attention and object substitution masking (OSM)**

9 F Beuth, F Hamker (Artificial Intelligence, Chemnitz University of Technology, Germany;
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The phenomena of visual attention (Hamker, 2005, Cerebral Cortex, 15(4):431-47) and object substitution masking (OSM; DiLollo and Enns, 2000, Journal of Experimental Psychology, 129(4):481-507) are supposed to rely on different processes. However, Põder (2012, Journal of Experimental Psychology) already suggested that attentional gating is sufficient and reentrant hypothesis testing is not required to explain OSM. However, present computational models have not been demonstrated to account for both phenomena at the same time. Based on a previous model of the frontal eye field (FEF) and the ventral stream (Zirnsak et al., 2011, European Journal of Neuroscience, 33(11):2035-45) we developed a novel neuro-computational model that allows to simulate OSM and common visual attention experiments, like biased competition and visual search. In biased competition and in OSM setups, multiple stimuli or stimulus and mask compete for visual representation by means of inhibitory connections, which accounts for the mask duration dependency in OSM. OSM also requires a high number of distracters (set size effect). Our model explains this observation by spatially reentrant

processing via a recurrent FEF-V4 processing loop. We conclude that OSM can be accounted for by well known attentional mechanisms within a unified model.

◆ **Functional subdivision of the visual field: vertical border evidenced by inhibition of return**

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Recent studies on spatial cueing effects suggest a functional subdivision of attentional control in the visual field [Bao and Pöppel, 2007, Cognitive Processing, 8: 37-44; Bao et al., 2012, Cognitive Processing, 13(1): 93-96]. Specifically, the periphery is significantly different from the fovea and perifoveal regions of the visual field. This eccentricity effect is very robust which is independent of cortical magnification [Bao et al., 2013, Experimental Psychology, DOI:10.1027/1618-3169/a000215] and resistant to subjects' practice [Bao et al., 2011, Neuroscience Letters, 500: 47-51]. However, all these observations come from the manipulation of stimulus eccentricity along the horizontal meridian. The present study further investigated the effects of inhibition of return (IOR) at different stimulus eccentricities along the vertical meridian in three behavioral experiments. Consistent with previous findings, IOR effects were significantly stronger at the more peripheral locations. The border between the two functional regions along the vertical meridian was at an eccentricity of approximately 6-8 degrees. The results suggest a functional dissociation of attentional control in the visual field with a narrower vertical border than the horizontal one as observed in previous studies.
[This work was supported by NSFC (No. 91120004).]

◆ **Neural evidence for the eccentricity effect of inhibition of return in the visual field**

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Spatial attention can be oriented towards both novel and previously attended locations in the visual field. However, a disadvantage of the latter is observed as indexed by the slower response time to targets. This phenomenon is termed "inhibition of return (IOR)" and has been extensively studied since mid 1980's. Recently it has been demonstrated that the magnitude of IOR is much stronger at the periphery relative to the perifoveal regions, suggesting an eccentricity effect of IOR [Bao and Pöppel, 2007, Cognitive Processing, 8: 37-44; Bao et al., 2013, Experimental Psychology, DOI:10.1027/1618-3169/a000215; Bao et al., 2013, Neuroscience Letters, 534: 7-11]. To further understand the neural correlates of the eccentricity effect, imaging studies were conducted using fMRI, ERP and MEG technologies. Compared to the perifoveal IOR which activated the typical fronto-parietal network, the peripheral IOR resulted in a surprisingly stronger involvement of prefrontal cortex [Lei et al., 2012, Cognitive Processing, 13(S1): 223-227]. The analyses of ERP components and global field power (GFP) using MEG also revealed a functional dissociation of IOR in the perifoveal vs. peripheral visual field. The results are consistent with previous observations as indicated by temporal processing, eye movement control or distinct neuroanatomical pathways.

◆ **The temporal dynamics of visual salience**

12 J Silvis, M Donk (Department of Cognitive Psychology, Vrije Universiteit Amsterdam, Netherlands; e-mail: j.d.silvis@vu.nl)

Whenever a novel scene is abruptly presented, visual salience merely has a transient role to play. Only those eye movements that are initiated fast enough appear to be driven by salience, whereas long-latency saccades or consecutive saccades are primarily under goal-directed control. However, it is still unclear under which circumstances salience may affect oculomotor behavior at a later moment in time. In a series of experiments, we examined how sudden changes in luminance affect initial and consecutive saccades. The results demonstrate that the oculomotor system is particularly susceptible to sudden increases in local salience, whereas sudden salience decreases turn out not to affect consecutive saccades. This suggests that, even in the case of a pronounced luminance change, it is not the change itself that affects the movements of the eyes. Rather, only when a stimulus suddenly stands out more, it will be able to attract saccades. Taken together, it appears that although salience only has brief effects, it acts

dynamically to allow the detection of distinct objects at any moment. The results will be discussed in terms of the implications for several views on visual selection.

◆ **Spatial and nonspatial visual selection**

13 M Nordfang, C Bundesen (Dept. Psychology, University of Copenhagen, Denmark; e-mail: maria.nordfang@psy.ku.dk)

It has long been debated how spatial and nonspatial categories influence visual selection [Logan, 1996, Psych Rev, 103(4), 603-649; Scholl, 2001, Cogn, 80(1-2), 1-46; van der Heijden, 1996, Percp & Psych, 5(8), 1224-1237]. We investigated this question by a new and simple approach. Ten participants completed 1920 trials each in an alphanumeric partial report. Participants reported the letters from arrays of 2, 4, 6, or 8 letters and 0, 2, 4, or 6 digits. Each display contained eight stimulus positions evenly spaced on the circumference of an imaginary circle. All positions were occupied on a given trial. Stimulus presentation was brief with exposure durations of 10 – 180 milliseconds, and the stimuli were post masked. We fitted the data to a mathematical model based on Bundesen's [1990, Psych Rev, 97(4), 523-547] theory of visual attention and estimated the attentional weight allocated to targets and distractors at each of the eight positions. Both target weights and distractor weights showed strong variations across spatial locations, but for each subject, the ratio of the weight of a distractor to the weight of a target at the same location was approximately constant. The results suggested that attentional weights are products of spatial and nonspatial components.

◆ **How automatic is Automated Symbolic orienting?**

14 D Hayward, C Dick, J Ristic (Department of Psychology, McGill University, QC, Canada; e-mail: dana.hayward@mail.mcgill.ca)

Recent studies have found that behaviorally relevant cues, like arrows, invoke a new form of attention – Automated Symbolic Orienting – where spatial attention is engaged by overlearned expectancies that are important for everyday behavior. Here we investigated whether spatial automated symbolic orienting depends on voluntary control engaged by explicit expectancies about when in time a target will occur. We assessed participants' performance in detecting a target when (i) spatial automated orienting was engaged in isolation using spatially nonpredictive arrow, (ii) voluntary temporal orienting was engaged in isolation using temporally predictive shape, and (iii) both spatial automated orienting and voluntary temporal orienting were engaged simultaneously. Both types of attention produced the expected orienting effects when they were engaged in isolation. Further, the two processes did not interact even when they were engaged simultaneously, with symbolic automated orienting remaining unaffected by concurrent voluntary orienting. These data dovetail with the accepted notion that spatial and temporal orienting generally operate in parallel and more specifically indicate that automated symbolic orienting is highly resistant to modulations from explicit voluntary processes.

◆ **Two sides of the same coin? Combined attention in overt and covert orienting.**

15 M Landry, J Ristic (Department of Psychology, McGill University, QC, Canada; e-mail: mathieu.landry2@mail.mcgill.ca)

We recently demonstrated that behaviorally relevant stimuli, like arrows engage a unique and independent attentional system, called automated symbolic orienting (Ristic, Landry & Kingstone, 2012, Frontiers in Psychology, 3, 560). Furthermore, we found that automated attention combined with endogenous attention when the arrow cue is used to engage both attentional systems (Landry & Ristic, 2012, Journal of Vision, 12(9), 673). Here we tested whether a similar combined attention effect is observed when participants are asked to execute saccadic eye movements toward a peripheral target. The speed of participants' responses was assessed in three attention conditions: (1) Automated attention, where a spatially nonpredictive arrow served as an attentional cue; (2) Endogenous attention, where a spatially predictive symbol served as an attentional cue; and (3) Combined attention, where a spatially predictive arrow served as an attentional cue. Attentional effects emerged in all three conditions, with the magnitude of the combined attention effect surpassing the magnitudes of both automated and endogenous attention. These data indicate that attentional systems combine similarly across oculomotor and manual response systems.

◆ **Object's size captures attention in a Temporal Order Judgment task**

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Proulx (2010, PLoS ONE, 5(12):e15293) showed that large objects can capture attention in a visual search task. The present study investigated whether a large stimulus produces an advantage in temporal latency when presented with a small one revealing a greater allocation of attention to larger stimuli. To address this question, 20 observers performed a temporal order judgment task, indicating which of two circles was presented first. In each trial, we presented one circle of constant size (1°) and another whose size ranged (3° or 5°). The circles position and the presentation order was randomized. The first circle appeared after an onset time of 100 ms and the second circle in sequence, after a variable interval: 0, 30, 60, 90, 120 and 150 ms. We calculated the point of subjective simultaneity (PSS) and the results showed a negative value to the circle of 3° (- 7,56 ms) and a positive value to the circle of 5° (+8,40 ms). t tests indicate that PSS values are different from zero and between them ($p<0,05$). This study provides further evidences that objects' size interfere in the distribution of attention and that there is a size difference limit to this effect.

◆ **Joint and visual shifts of attention are based on similar mechanisms – or are they? An individual differences approach**

17 U Leonards, C Hedge, H Thiel, R Taylor, A Broyd, J Clark, A Rowe (School of Experimental Psychology, University of Bristol, United Kingdom; e-mail: ute.leonards@bristol.ac.uk)

To establish whether the temporal profiles for spatial shifts of visual and joint attention are in line with assumptions about overlapping neural mechanisms, and to see whether the speed of shifting attention is linked to object preferences for socially cued objects, 83 participants performed an object categorization task with social (eyes) and neutral (arrow) cues (e.g. Bayliss et al, 2006, Psychonomic Bulletin & Review, 13(6): 1061-1066). Unexpectedly, cueing indices for median reaction times (RTs) revealed no significant correlations between social and basic visual shifts of attention, but social cueing indices for RTs correlated highly with object preference indices. Multi-level regression modelling confirmed the important role of individual differences in object preferences induced by joint attention shifts, with more than half of the variance in preference ratings accounted for by differences in participants' overall response patterns and task manipulations such as cue type: RTs had a prominent association with preference ratings, suggesting a common mechanism underlying the speed with which object discrimination is performed under joint attention conditions and later preference ratings of the objects used during the task. Moreover, individual differences in personality traits identified several personality dimensions as relevant to task outcomes, including Sensation Seeking and Schizotypy.

◆ **Effects of different stimulus onset asynchronies on visual attention shifts**

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Previous studies have reported that a directional visual stimulus, such as eye gaze, triggers an automatic shift of visual attention toward the direction indicated by the stimulus. This occurs at very short stimulus onset asynchronies (SOA; the time between the onset of the directional stimulus and the onset of the target). In this study, we examined in detail the effects of different SOAs on visual attention. Twelve undergraduate students performed a localization task involving a target presented either to the left or to the right on a screen. Eye gaze, arrows, Chinese characters, and English capital letters (R/L) were used. The SOAs were 50, 75, 100, 150, 200, 250, 300, 350, 400, 500, 600, and 1000 ms. Three SOAs were combined and fixed in a test block and assigned randomly to a participant. We found that response time (RT) gains for arrows were greatest for the shorter SOAs. The gains were primarily caused by the interference effect, as responses were significantly delayed in the invalid trials. For face stimuli, the RT gain was greatest at a SOA of 100 ms, consistent with previous studies. Chinese characters and English capital letters did not show a significant RT gain.

◆ **Time course of attentional shift in response to another person's gaze direction**

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The gaze direction and head orientation can capture an observer's attention. We investigated when this capture occurs, employing three-frame stimuli; in the first frame, a face with the straight gaze was presented. In the second frame, the eyes, head or both of them were presented as 30 deg rotated images for 40 ms. Finally, in the third frame, the eyes and head were presented as 60 deg and 30 deg rotated images, respectively, in the same direction as that in the second frame. We examined which frame was important for the observer's attentional shift. The task of the observers was to respond to a target which appeared in the left or right of the visual field as quickly and correctly as possible. The results showed that the direction of gaze or head contributed to shortening reaction times when the eye/head rotation direction and the target direction were congruent in the second frame. The third frame further shortened the reaction times in the congruent condition. We conclude that an observer's attention was captured at the beginning of the eye/head rotation with a short latency and that the attentional shift was further strengthened by the following eye/head rotation.

◆ **Stimulus-driven effects on line bisection behavior: An EEG study**

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A systematic leftward bias (pseudoneglect) is typically exhibited by healthy young adults during performance of line bisection tasks. However, the bias is modulated by stimulus factors such as line length. The processes underlying modulation of bias magnitude and direction remain unknown. A possible explanation is that bias level depends on the extent to which the spatially dominant right hemisphere is engaged by the combination of stimulus and endogenous state during performance of the task. During performance of a perceptual line bisection task in both long and short lines, we discovered long lines to induce an increased hemispheric asymmetry of electrophysiological processes implicated in visuospatial processing relative to short lines. Increased right hemisphere utilisation in long lines occurred within the P1/N1 ERP complex, and was found to correlate with line bisection bias direction/magnitude across participants. The results suggest that the common leftward bias displayed in pseudoneglect is a function of right hemisphere dominance during early stimulus-driven indices of visual processing.

◆ **Emotion-attention resource competition in early visual cortex follows emotional cue extraction**

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When allocating attention to the world, visual stimuli compete for limited neural processing resources. In our previous studies, we found that emotional stimuli have an advantage in this competition. We investigated the time course of competition between distracting task-irrelevant emotional background images (IAPS) and a to-be-attended visual foreground task. After approximately 400ms, more attentional resources are withdrawn from the foreground task to background affective than to neutral images, which is reflected in a significant drop in the steady state visual evoked potential (SSVEP). The extraction of the emotional affect preceded this amplitude reduction, as indicated in an early posterior negativity (EPN; 240ms). However, for faces, emotional extraction may occur earlier, with effects of emotion seen in the face-specific N170. If affective modulation of SSVEP amplitudes follows emotional cue extraction, then it should occur earlier for faces than for IAPS images. We confirmed more negative deflections for emotional stimuli in the EPN (330ms) to IAPS and the N170 (175ms) to faces. Furthermore, SSVEP amplitudes dropped significantly more for emotional stimuli at approximately 200ms with faces but not until approximately 500ms for IAPS images. Thus, the time course of competition bias seems to be linked to the latency of emotional cue extraction.

◆ 22 **Attention spreads measured by steady state visual evoked potential and by event related potential**

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We investigated spatial spreads of visual attention, measuring EEG components called SSVEP (Steady-State Visual Evoked Potential) and ERP (event related potential). SSVEPs are sinusoidally-evoked potentials induced by constantly flickering stimuli, having the same frequency as stimulus frequency and ERP is the potential evoked by stimulus presentation. Since both components are modulated by attention, spatial spread of visual attention can be estimated by measuring them at different locations. There were eight stimuli arranged circularly at a fixed distance from the fixation point. A cue was presented at one of the eight locations and an RSVP (rapid serial visual presentation) task was given at the location. We found that clear peaks in SSVEP signals at frequencies corresponding to stimulus flickers and that the amplitude was modulated by attention. We also found that the p300 component of ERP to the RSVP target was modulated by attention. The attention modulation of ERP showed gradual decrease with the distance from the cued location whereas p300 showed clear attentional modulation only at the cued location. The difference can be interpreted by assuming that SSVEP and p300 reflect characteristics of different levels of the attention system.

◆ 23 **Do Stroop congruency levels modulate early and late feature-based attention effects? An ERP study**

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Non-spatial attention to different feature stimuli is associated with distinct modulations in ERP components. Both the Selection Negativity (SN), reflecting early attentional selection mechanisms, and the P3, presumed to underlie stimulus evaluation processes, demonstrate a larger amplitude for attended than unattended features. The present study addresses the question how these feature-based attention components are modulated by stimulus congruency in an interference task. A version of the Stroop task was combined with feature cues directing attention to the upcoming target color. The cues were valid or invalid and the Stroop stimuli were either congruent, incongruent or neutral. Behavioral and EEG data from 12 participants were analyzed. The attention effect with neutral Stroop stimuli served as a baseline and was compared with the attention effects associated with congruent and incongruent Stroop stimuli, respectively. It was hypothesized that the SN and the P3 would be differentially altered by the stimulus congruency level. Thus, invalid cueing was expected to lead to more elaborate processing of the stimulus word, causing opposing effects for congruent compared with incongruent stimuli. Accordingly, preliminary data analysis suggests that the distribution of the attention effect (both SN and P3) was altered for these stimuli when compared to the baseline.

◆ 24 **Feature-based attention effects for motion and color changes assessed with ERPs in a cue validity balanced paradigm**

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Behavioral studies investigating the influence of selective attention on visual processing often adopt higher proportions of valid trials. This circumstance, however, may lead to a novelty response for the infrequent invalid condition, thus impeding a proper comparison of different attentional conditions. Here, we used an experimental design with equal probabilities for both validity conditions. The task required detection of changes (color or speed) in two superimposed random dot kinematograms. The feature dimension cue had a validity of 50% whereas the target object was always validly cued. Behavioral data of 10 participants confirmed significant feature-based attention effects for both dimensions. However, permutation statistics show that the selection negativity (SN), an early ERP component usually increasing in the attended condition, was only visible for color changes, whereas in the time window of the P3 component centro-parietal attention effects were present for both conditions. Our results show that differences in performance as derived from behavioral studies using cues with unequal probabilities (e.g. Posner paradigms) are unlikely to be induced by a novelty response due to the less frequent condition, but rather reflect different attentional states. The lacking SN effect for the motion condition will be discussed.

◆ **Rhythmic presentation of category-specific but different stimuli drives oscillatory brain response**

25 C Keitel, K Saupe, E Schröger, M Müller (Institute for Psychology, University of Leipzig, Germany; e-mail: keitel@rz.uni-leipzig.de)

Rhythmic visual stimulation at a given rate elicits oscillatory brain activity with the same temporal frequency. We investigated whether this so-called steady-state response (SSR) can also be driven by a regular presentation of different stimuli that belong to a common symbolic category. To this end participants viewed a 15-Hz rapid serial visual presentation (RSVP) of letters (L), numbers (N) and unfamiliar symbols (U). Numbers or letters were presented at each third position, i.e. at 5 Hz in the RSVP stream, respectively. Symbols of the remaining two categories were interspersed in random order (Example sequence: ... UL[N]LU[N]LU[N]...). Participants were cued to attend to letters or numbers and to report occurrences of color-tagged symbols of the cued category. Regular presentation of either category drove a robust 5-Hz SSR whose amplitude modulated with task-relevance of the driving symbols. Source reconstruction revealed distinct cortical origins of the category-specific 5-Hz SSR and the 15-Hz SSR driven by the RSVP. Hence, the 5-Hz SSR may demonstrate the ability of the human brain to entrain to a more abstract regularity beyond physical stimulus repetition.

◆ **Neurophysiological evidence for enhanced top-down control in processing of homogeneous contexts**

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There is an ongoing debate to what extent irrelevant salient information attracts an observer's attention and is processed without the observer intending to do so or whether volitional control can be very efficient already at an early point in visual processing. In the present experiment we used behavioral measures and event-related potentials in an additional singleton paradigm to show that the relative contribution of top-down and bottom-up processing depends on the homogeneity of the context stimuli are embedded in. Results indicated faster and more pronounced attention allocation for targets in more homogeneous contexts. In addition, we found delayed active suppression of salient distractors in less homogeneous contexts. In sum the present results suggest that top-down control of attention is stronger the more homogeneously stimuli are arranged.

◆ **Perceptual processing during divided attention across and within visual hemifields**

27 S Walter, C Keitel, M Müller (Institute for Psychology, University of Leipzig, Germany; e-mail: sabrina.walter@uni-leipzig.de)

According to the different-hemifield advantage, responses to stimuli distributed across the two hemifields are faster and more precise than responses to stimuli that fall within one hemifield. Here we aimed to investigate this phenomenon with a divided attention paradigm. We presented six LEDs that were aligned on a semi-circle in the lower visual field, each flickering at a different frequency. Participants were asked to attend to two LEDs that were spatially separated by an intermediate LED, and to respond to simultaneous events at the attended LEDs. To perform the task they had to divide their attention within one or between both hemifields. We recorded the electroencephalogram and analysed amplitudes of continuous oscillatory brain responses, so-called steady-state visual evoked potentials (SSVEPs) that were elicited by LED flicker. SSVEP amplitudes index attentional allocation and, hence, allow inferences on the processing of individual components of multi-element displays. Only when attention had to be split across hemifields, processing of LEDs at intermittent to-be-ignored positions was significantly reduced. This finding was supported by corresponding behavioural data. Thus, results suggest that dividing attention between locations that are distributed across hemifields is easier than between locations that fall within one hemifield.

◆ **Cartography of causal contributions of human frontal cortex to visual attention**

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The human frontal cortex is involved in the allocation of visual attention, however, the exact causal functional contributions of individual subregions are not well understood. Using a simple visual localization task we applied rTMS pulses to map frontal cortical subregions likely to generate significant visuo-spatial biases during the spatial deployment of attention prior to perception. Nine subjects executed

a task based on the localization of small dots, briefly (40ms) displayed unilaterally (left or right) or bilaterally (left and right). In a systematic mapping approach, a stimulation grid of 9 (3x3) sites was anchored 2 cm rostral to the motor hand area. Three pulses of real or sham 10 Hz rTMS were delivered at each of the grid locations 50 ms post target onset to interfere with the ongoing neural processing. As a main finding, significant deterioration of detection performance for stimuli in the contralateral hemifield and increased performance for ipsilateral targets were observed for two grid regions anatomically associated with the right FEF and right middle frontal gyrus. We conclude that the disruptive effects of TMS on a simple spatial localization task, requiring a well-balanced deployment of attention, are exquisitely spatially selective, and are found in specific frontal cortical subregions.

◆ **Cued Attention and Aesthetic Evaluation of Abstract Unfamiliar Patterns**

29 G Rampone, A Makin, M Bertamini (Department of Psychological Sciences, University of Liverpool, United Kingdom; e-mail: m.bertamini@liv.ac.uk)

The link between attention and affect has been studied before, in particular in relation to the distinction between targets and distracters, and in relation to social cues. It has been suggested that simple cuing of attention does not in itself changes the evaluation of a stimulus (Bayliss et al., 2006 Psychonomic bulletin & review, 13, 1061-1066). However, we decided to explore in more detail the effect of cuing because exogenous cues may be more effective than endogenous cues, and because the role of eye movements has not been studied before. We used a variation of Posner's paradigm in which participants' attention was cued to one side of the screen by a flashing light, and observers performed a saccade. Our targets were abstract unfamiliar patterns that varied in degree of regularity. As expected, the more regular patterns were preferred over the random ones. Moreover, we found some preliminary evidence that the target at the valid location was evaluated more positively than the target at the invalid location.

◆ **Visuospatial working memory mediates the preview effect in the absence of attentional**

30 **capture**

D Barrett, S Shimozaki (School of Psychology, University of Leicester, United Kingdom; e-mail: djkb1@le.ac.uk)

Search performance is enhanced when a subset of the distractors is presented prior to the onset of the search display. This enhancement, known as the preview benefit (Watson & Humphreys, Psychological Review, 104: 90-122), is usually attributed to one of two mechanisms: the top-down inhibition of old-items in the preview display or the bottom-up capture of attention by new-items in the search display (Kunar et al., Psychological Science, 14: 181-185). According to the latter, the preview benefit is independent of visuospatial working memory (VWM). To test this assertion, we used signal detection analyses to compare target discriminability (d') when the presence and temporal relationship between the preview and search displays varied. Targets in search displays preceded by an asynchronous preview display elicited higher d's than those in a no-preview condition. Targets in preview displays that disappeared for 2 seconds before being presented synchronously with the search display, also elicited higher d's than the no-preview condition. Importantly, this benefit occurred in the absence of luminance onsets distinguishing old from new items. This result indicates that competition between old and new items in preview search can be mediated by VWM, particularly when the temporal cues that elicit attentional capture are removed.

◆ **Working memory precision is affected by priority of locations**

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The concept of priority map theory posits a neural mechanism for ranking important locations in the space based on visual saliency and goal-relevant stimulus features (Itti and Koch, 2001; Fecteau and Munoz, 2006). Presumably, neural activity within topographically organized maps of visual space in frontal and parietal association cortex code for prioritized locations (Jerde at al, 2012; Serences and Yantis, 2007). Our goal here is to distinguish priority maps from other models of spatial attention (e.g., "spotlight of attention"). To do so, we conducted two psychophysical working memory experiments in which subjects maintained cued locations with different priorities. In study 1, we showed that the probability that one's memory for an item will later be tested is proportional to the precision of the item representation in working memory. In study 2, we showed that monetary incentives associated with an item are proportional to the precision of one's memory for the item. Overall, the results from these two studies demonstrate that the relative priority of multiple items affects the precision of working

memory. These data suggest the relative importance of multiple locations can be simultaneously encoded, theoretically, in prioritized maps of space.

◆ **Learning eye movement sequences (scan paths) in a number connection test: Evidence for**
32 **long-term memory based control of attention**
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In well-learned sequential sensorimotor tasks, humans perform highly systematic scanpaths with fixations on upcoming target locations [e.g., Foerster et al., 2012, Journal of Vision, 12(2):8, 1-15]. However, it is not clear whether systematic scanpaths can also be learned if hand movements are not required. To test scanpaths characteristics in the absence of manual actions, we investigated an oculomotor version of the number connection test. Participants had to look as fast as possible at numbered circles in ascending order (1 – 9). During an acquisition phase, participants accomplished 100 trials with the same spatial arrangement of 9 circles. Overall, they became faster and performed fewer fixations. In addition, the distance of fixations to the upcoming target circle decreased. In a consecutive retrieval phase, a blank screen appeared and participants were asked to look at the empty screen in the same order as during the acquisition phase. Participants were able to perform this complex sequential sub-task with highly similar scanpaths across sub-tasks. Results imply a LTM-based control of sequential attention shifts and eye movements in well-learned sequential tasks even if visual information is no longer available.

◆ **Altering attentional control settings causes persistent biases of visual attention**
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Internal biases have an important role in guiding visual attention however, little is known about how attentional bias initially develops. Here, we show that it is possible to induce an attentional bias towards an arbitrary stimulus (the colour green) using a single information sheet and assessed through a change detection task. After an interval of either 1 or 2 weeks participants were then either re-tested on the same change detection task, or tested on a difference change detection task where colour was irrelevant. This latter experiment included trials where the distracter stimuli (but never the target stimuli) were green. The key finding was that green stimuli in the second task attracted attention, even though they were explicitly irrelevant. The induced attentional bias altered participants' sensitivity towards bias-related stimuli (calculated via d') and persisted for at least two weeks. We speculate that changes to attentional control settings account for these findings. Attentional bias has an established role in the persistence of various psychopathologies such as addiction, however our findings explore the phenomenon outside of emotional and neurochemical factors confounding previous studies of attentional bias. We suggest an underlying shared cognitive basis of attentional bias upon which the pathology-specific aspects are built.

POSTERS : EYE MOVEMENTS

◆ **Why there is less peri-saccadic compression in the dark**
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Flashes presented near the time of a saccade are judged to be nearer the saccade endpoint than they really are. This peri-saccadic compression of perceived positions might result from a foveal bias that influences localisation whenever there is uncertainty about when a flash occurred relative to the saccade. Such a bias probably reflects prior expectations: people are most likely to see something if their gaze is directed at it, so if they saw it they are likely to have been looking at it. If so, why is there less peri-saccadic compression when flashes are presented in the dark than in the light? To examine whether a larger range of flash positions should be considered likely in the dark, we determined how the light level influences the likelihood of detecting flashes at different retinal locations in the presence of moving distracters. We compared a photopic and a scotopic condition. The relative likelihood of detecting flashes at higher eccentricities was higher in the dark than in the light, presumably because rods are more uniformly distributed across the retina than cones. This result supports the idea that the difference in peri-saccadic compression results from context-dependent prior expectations about perceived objects' retinal locations.

◆ **Peri-saccadic visual motion and saccade accuracy estimation**

35 T L Watson (Foundational Processes of Behaviour, University of Western Sydney, Australia; e-mail: t.watson@uws.edu.au)

It has been suggested that stimuli not perceived during a saccade may still serve a visual function. Visual motion that does not match that expected to be generated by making a saccade may be useful for estimating saccade endpoint errors and inducing subsequent corrective saccades. This was tested by presenting a brief moving dot field stimulus during a saccade, moving with or against the saccade. It was predicted that the motion may induce a catch-up saccade to correct for the unexpected peri-saccadic visual motion and that the direction of the saccade would match that of the direction of the visual motion. This was not found to be the case. Corrective saccades were made on approximately half of all trials however the number and direction of these saccades did not depend on the direction of peri-saccadic motion. Additionally, there was no difference in the size of the corrective saccade depending on the distance travelled by the motion stimulus. This suggests that visual motion generated by making a saccade is not used to estimate post saccade fixation accuracy.

◆ **Peri-saccadic spatial compression in dyslexia**

36 F Maij, J Atsma, P Medendorp (Donders Institute, Radboud University Nijmegen, Netherlands; e-mail: f.maij@donders.ru.nl)

When reading, the eyes jump from word to word. Each saccadic eye movement causes a shift in the retinal image, which must be compensated for by the brain in order to create a stable percept of the text. Could an insufficient compensation explain deficits that are seen in dyslexic readers? A typical paradigm to test this compensatory mechanism examines the localization of flashes presented near the time of saccades. Non-impaired participants mislocalize flashes, as if visual space is compressed toward the saccade endpoint. The size of this compression depends on various factors, including saccade kinematics. Interestingly, recent studies have suggested that peri-saccadic compression in dyslectic participants is attenuated compared to non-impaired controls. However, because saccadic characteristics differ also in dyslexics, the question arises whether this difference in compression is simply due to differences in eye movement behavior. In this study, we tested peri-saccadic compression as a function of saccade kinematics in both dyslexics and controls, by manipulating saccade amplitude between 10 and 14 degrees. We found a clear effect of saccade amplitude on peri-saccadic compression in controls. Preliminary findings suggest that compression effects differ between dyslexics and controls. More experiments and analyses are currently under way to validate this notion.

◆ **No evidence for peri-saccadic mislocalization on suddenly cancelled saccades**

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Around the time of saccadic eye movements, visual stability is distorted: briefly-flashed stimuli presented up to 150 ms prior to the saccade are systematically mislocalized. One possibility could be that the origin of this mislocalization is a result of saccade planning. To test this, we combined a countermanding task with a peri-saccadic mislocalization task. Subjects performed 1600 trials each, reporting the perceived location of a briefly-flashed stimulus on trials with or without an imperative stop signal, timing the stop signal so that subjects cancelled 50% of stop-signal trials. By estimating the time needed for saccade cancellation and using the history of recent reaction times, we were able to examine mislocalization relative to the point of no return. While systematic mislocalization was evident on trials without a stop signal and on non-cancelled trials, we saw no evidence for systematic mislocalization on any cancelled trials, even if they were cancelled very close to the point of no return. These results show that the distortion of visual stability is gated by the saccade.

◆ **The phantom gap: an objective measure of para-saccadic masking**

38 M Duyck, T Collins, M Wexler (Laboratoire Psychologie de la Perception, CNRS & Université Paris Descartes, France; e-mail: marianne.duyck@parisdescartes.fr)

While we move our eyes under ordinary viewing conditions, we are not aware of the smears caused by the rapid visual motion on the retina during saccades. One explanation is that the smear is being masked by pre or post-saccadic static images. Evidence comes from subjective reports in experiments displaying a dot at different times around a saccade: if the dot is presented during the saccade only, observers perceive a phantom-like smear parallel to the saccade; but if it is also present before (forward mask) or after (backward mask) the saccade, shorter smears or single dots are perceived instead. We lit

an LED during a saccade and inserted a brief luminosity decrement, resulting in the percept of an even more phantom-like gap inside the smear. By varying the time of the decrement we varied the position of the gap, which observers could reliably report using the method of single stimuli. We also varied the presence and duration of pre- and post-saccadic masks. Masks led to a large decrease in the slope of the psychometric function. This technique provides an objective measure of para-saccadic masking that may contribute to the study of its relation to classical or "fixational" masking.

◆ **Transsaccadic prediction of object identity: Evidence from visual search and object recognition**

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This study investigates whether peripheral and foveal representations of an object become associated across saccades and how such associations are used for visual search and object recognition. In an acquisition phase participants made saccades to peripheral objects. For one object, features did not change across saccade, so that one and the same object was presented to the peripheral and central retina (normal exposure). For another object, we consistently changed a feature in mid-saccade, so that slightly different objects were presented to the peripheral and central retina (swapped exposure). Transsaccadic learning was assessed in two different test phases. In Experiment 1, participants made eye movements to peripheral objects and were asked to choose a foveal test object matching the peripheral object (object recognition). In Experiment 2, we briefly presented a target object in the fovea and asked participants to search this object in the periphery (visual search). Both experiments revealed better performance for acquisition congruent combinations of peripheral and foveal objects as compared to acquisition incongruent combinations. This suggests that transsaccadic associations are utilized to predict how peripheral objects might appear in the fovea (relevant to object recognition) and how searched-for objects might appear in the periphery (relevant to visual search).

◆ **Saccadic Inhibition – Sudden target offset upsets saccadic generation**

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Saccadic inhibition describes the effect on saccadic generation toward a target by sudden onset of a distractor, effectively suppressing saccade generation 90-100 ms after distractor onset. Less well established is the effect of sudden disappearance of a target. Increasing stimulus duration should lead to a decrease in response latency and increase in performance, since stimulus energy increases as well. However sudden disappearance of target may inhibit saccadic responses altering response time distribution and thereby influence performance. Here we present results of a 2 AFC experiment, in which participants had to indicate via saccade the position of an animal contained in one of two natural scenes. Stimulus duration was varied between 5 ms, 65 ms, 125 ms, 185 ms and 400 ms. Surprisingly, even if increased stimulus duration permits more information access, participants become worse in performance but nonetheless response latencies apparently decreased. Closer inspection of response time distribution reveals an observable dip in saccadic generation 120 ms after stimulus extinction, making a simple speed accuracy tradeoff unlikely. It seems saccadic response is not only inhibited by sudden appearance of a salient object but also by a salient off signal arising from stimulus offset.

◆ **Saccadic suppression during monocular visual stimulation**

41 J Knöll, P Holl, F Bremmer (Department of Neurophysics, Philipps-University Marburg, Germany; e-mail: jonas.knoell@physik.uni-marburg.de)

Saccadic suppression describes the reduction of luminance contrast sensitivity at low spatial frequencies around the time of saccades. Its origin is yet unclear as is the question whether it is based on binocular or monocular neural processing. In the latter case, contrast sensititivty should not depend on the movement of the non-stimulated eye during monocular stimulation. Contrast sensitivty was measured psychophysically in a 2AFC task. Human observers performed saccades in depth to targets aligned in front of one of the two eyes. This resulted in temporally aligned saccades of different size and velocity for the two eyes. Participants indicated the perceived location of a low spatial frequency stimulus with variable luminance that was presented monocularly to either eye above or below the horizontal meridian. When analyzed with respect to the eyes' individual velocity, the contrast sensitivity for a given velocity differed between the faster and the slower eye. When analysis was based on the velocity of the faster eye, contrast-sensitivity functions were comparable for stimulation of either eye. We conclude that saccadic

suppression does not depend on the speed of the stimulated eye but rather on the ocuolomotor control of both eyes. Support: Deutsche Forschungsgemeinschaft (GRK-885, FOR-560) and EU MEMORY

◆ **Saccadic suppression of displacement and adaptation: flip sides of a coin?**

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When a visual target is displaced during the saccade towards it, the displacement is often not perceived, a phenomenon known as saccadic suppression of displacement. However, such displacements cause saccadic adaptation: the amplitude of the following saccade corrects for some of the (artificial) error of the previous trial. Suppression and displacement have often been studied independently, although both are measured by the in-flight target displacement task. In the present experiment, both effects were measured concurrently. Preliminary results show that adaptation correlates with suppression on a trial-by-trial basis. These results suggest that future behavior is adapted only when the cause of previous inadequate behavior is attributed to a movement error, not when it is attributed to a change in the outside world.

◆ **Dummy eye measurements of microsaccades**

43 F Hermens (University of Aberdeen, United Kingdom; e-mail: f.hermens@abdn.ac.uk)

Microsaccades are small movements of the eyes made during visual fixation. Many of the investigations of these microsaccades have used a video-based eye tracker for their detection. We here investigate how reliable this method is by comparing the detection of microsaccades for one of these systems (Eyelink II) when recording from human eyes and a pair of dummy eyes. Dummy eyes were either fixed on a stationary dummy head or the dummy eyes were attached to a pair of glasses worn by a human participant. False detections were infrequent for stationary dummy eyes, indicating that the intrinsic noise of the video-based eye tracker did not result in signals resembling those from microsaccades. The number of false detections increased when the dummy eyes were mounted onto a human head, indicating that small movements of the head resulted in signals that could be interpreted as microsaccades. However, differences between detected microsaccades from actual eyes and dummy eyes were found, such as the absence of a clear correlation between the directions of the microsaccades in the two dummy eyes, which can be used to improve the method for detecting microsaccades.

◆ **Microsaccades parameters in special visual tasks**

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Microsaccades parameters were investigated in three different types of visual tasks: 1) the sustained fixation task; 2) the preparing for oculomotor task (gaze redirection on three different distances); 3) the two-points visual acuity task. In the oculomotor task participants were asked to fixate the target in its first position in the center of the display and then to direct their gaze as accurately as possible to its second location and hold fixation until the end of the trial. Second target location was changed randomly from trial to trial and was in one of eight angular positions with one of three eccentricities: 75, 280 or 485 arcmin. A cue (a grey circle around the target in first position) indicating a predetermined eccentricity of a subsequent target location was presented 2000 ms before target displacement in 2/3 of trials. In the two-points visual acuity task participants were asked to discriminate two points with angular sizes from 1 to 4 arcmin and the same angular distances. Preliminary analysis did not reveal significant difference between microsaccades amplitude and velocity values in three types of the visual tasks.

◆ **Immediate preparatory influences on microsaccades before saccade onset to endogenously**

45 **vs. exogenously defined targets**

S Ohl[1], S Brandt[1], R Kliegl[2] ([1]Charité Universitätsmedizin Berlin, Germany; [2]University of Potsdam, Germany; e-mail: sven.ohl@charite.de)

During fixation, small-amplitude eye movements are observed. So called microsaccades can be influenced by bottom-up and top-down processes and they are thought to share many aspects of large saccades, just on a smaller amplitude-scale. In the present experiment, we study whether preparatory processes modulate microsaccade statistics (e.g., rate and amplitude) before execution of a response saccade. To this end, we examined microsaccades before saccades to targets defined by an endogenous vs. exogenous cue in a blocked design. We observed a strong preparatory influence on microsaccade statistics in terms of a higher microsaccade rate before endogenously as compared to exogenously

defined targets. This effect was further substantiated by an additional influence of target eccentricity. The modulation of microsaccade rate as a function of the preparatory set can be explained by a model of microsaccade generation, which is based on two assumptions. First, microsaccades are generated in the center of a saccadic motor map, while increasingly distant sites from the center code for increasingly large saccades. Second, attending a location in the visual scene increases activity at the corresponding site in the saccadic motor map. Thus, our study provides important insights into the implementation of immediate preparatory processes on microsaccade generation.

◆ **Persistent inhibition of microsaccades caused by attentional concentration**

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Recent studies have shown that the mechanisms responsible for microsaccades, which are small involuntary shifts in eye-gaze position, are related to the visual attention system. These studies have shown that microsaccade rates increase with shifts in attention allocation. In contrast, other studies have shown that microsaccades are inhibited when visual attention is intensely applied on a fixed target. It has not yet been established which of these conclusions is correct. In this study, we hypothesized that the microsaccade rate would decrease according to the degree of attentional concentration. Subjects performed RSVP tasks by maintaining their fixation on the alphabetical characters that were displayed at the center of a CRT monitor. The degree of attentional engagement of the subjects was controlled by changing the target character contrast. We then analyzed the relationship between the microsaccade rate and the degree of attentional engagement. The microsaccade rate was suppressed simultaneous with the display of the target objects and was increased after the target was extinguished. When higher concentration was required, the inhibition of microsaccade occurrence was prolonged. These results suggest that the microsaccade rate was inhibited according to the concentration of visual attention in the foveal region.

◆ **Your eye movements tell who you are**

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It has been shown that when observing a visual scene, people show eye movements that are unique to individuals. This is not surprising because different individuals often attend to different objects in the scene. The present study explored fundamental and intrinsic characteristics of eye movements that directly reflect individuality. We measured participants' eye movements while they made a short speech in front of several ordinary scenes (e.g., class room) projected onto a large screen. A discriminant analysis of physical properties of their eye movements distinguished between individuals with high accuracy regardless of the scene. We also found the consistency of one's eye movements between the periods when participants were preparing the content for their speech and when they were giving the speech. Even after seven months, we found their eye movements are very similar to those measured in the first experiment. The independence from the visual environment and a given task, as well as the long-term consistency suggests that spontaneous eye movements express who s/he is. We also showed that human observers can identify individuals by seeing computer-generated animations simulating real eye movements. The eyes may convey individual character to others and play some roles in interpersonal communication.

◆ **The influence of figure-ground organization on saccadic eye-movements**

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Previous research [Ghose, Hermens & Wagemans, ECVP 2012; VSS, 2012] suggested that saccade latencies can be used as an indirect measure of the strength of perceptual grouping. Research on figure-ground organization has shown that cues that bias a region to be figural e.g., Convexity, Familiarity and presence of 3D-convexity and Extremal-Edges, differ in relative strength [Ghose & Palmer, JOV 2010]. In this study we measure whether the time to initiate a saccade to a target was slower when it appeared in a location incongruent rather than congruent with a bipartite display with one side biased by a figural cue. We found that of the cues tested only 3D-convexity-with-no-Extremal-Edge resulted in a significant difference in the saccadic latencies for congruent and incongruent conditions. Cues such as Convexity, Familiarity, and Extremal-Edges did not lead to significant differences. The pattern of results

did not change even when there were a few 3D-convex distractor images on the display in addition to the bipartite figure-ground image. The results indicate that the strength of figural bias does not affect implicit eye-movement measures and probably additional processing happening in-between the first saccade to the image and the manual response leads to the strength differences reported previously.

◆ **Influence of saccade direction on illusory motion**

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Repeated patterns of asymmetric luminance gradients induce illusory motion perceptions [Kitaoka and Ashida, 2003, Vision, 15, 261-262]. Otero-Millan et al. [2012, The Journal of Neuroscience, 32(17), 6043-6051] have demonstrated that saccades are one of the triggers of such illusory motion. However, it is unknown whether saccade direction affects the magnitude of the illusion. We examined the directional selectivity of the illusion relative to the saccadic direction. The experimental stimuli were illusory patterns that appeared to move vertically or horizontally. In each trial, participants observed the stimulus with their eyes saccading vertically or horizontally, and they reported the magnitude of the illusory motion. We found that the magnitude of the illusion was significantly smaller when the direction of the illusory motion and the direction of the saccade were parallel compared to when they were orthogonal and when eye movement was unrestricted. We concluded that there was directional selectivity between the directions of the illusory motion and the saccades, and this might reflect a suppressive mechanism for the illusory motion.

◆ **Gain of memory guided saccades is modulated by prefrontal dopamine**

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Memory guided saccades require the subject not only to control occulomotor behavior voluntarily, but also to encode and remember the spatial position of a target precisely. Here we were interested in how supposed differences in prefrontal dopaminergic activation in healthy adults affect accuracy and precision of saccades to remembered targets. Catechol-O-methyltransferase (COMT) plays a major role in the regulation of prefrontal dopamine levels. The COMT val158met polymorphism modulates enzyme activity in that met alleles lead to less active dopamine degradation in prefrontal cortex and accordingly to higher dopamine levels. We investigated memory guided saccades in 105 subjects and determined the individual genotypes. While subjects were fixating a target was presented for 200 ms at one of three randomly varied horizontal positions (4, 10, and 16 deg). After a delay of 1500ms the fixation point changed its color and subjects were supposed to saccade to the remembered target position. We found a significant effect of genotype on average gain ($F(1, 105)=4.11$, $p=.045$, $h2=.04$) and a statistical trend for gain variability ($F(1, 105)=3.00$, $p=.086$, $h2=.03$). Met homozygotes (n=31) showed lower average gain and higher gain variability than val allele carriers. Our results provide evidence of dopaminergic modulation of saccadic accuracy and precision.

◆ **Evaluation of visual factors of visually induced motion sickness by analyzing fixation eye**

51 **movements and heart rate variability**

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Videos containing strong vibrational or rotational motion may cause some symptoms similar to motion sickness such as nausea, dizziness and headache, which is called visually induced motion sickness (VIMS). In order to identify the effective motion component for VIMS, we have analyzed heart rate variability and fixation eye movements of subjects viewing videos of which content was restricted to certain visual factors. First, we analyzed fixation eye movements by spectral analysis while subjects were watching random dots which consist of each of three visual factors, such as Pan, Roll and Zoom. The results showed that variability of the eye movements was increased as the experiment session progresses. It means that it is difficult to maintain the attention of fixation as VIMS progresses. Second, we evaluated the heart rate variability while subjects were watching the motion pictures which were not random dots but well controlled motion pictures of an indoor scene and an out outdoor scene. Spectral analysis of the heart rate variability demonstrates that HF/LF measure in the Pan condition has lower

values than in the Roll condition. It suggests that Pan motion in the video increases sympathetic nerve activity and it is the most effective visual factors of VIMS.

◆ 52 **GraFIX: Developing a novel semi-automatic approach for detecting fixation durations in low quality data from infants and adults**

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Fixation durations (FD) have been used widely as a measurement of information processing in infants. Common issues with testing infants (e.g. high degree of movement, unreliable eye detection) result in highly variable data quality and render existing FD detection approaches highly time consuming (hand-coding) or imprecise (automatic detection). To address this problem we developed GraFIX, a novel semi-automatic method consisting of a two-step process in which eye-tracking data is initially parsed by using adaptive velocity and dispersal-based algorithms, before it is hand-coded using the graphical interface, allowing accurate and rapid adjustments of the algorithms' outcome. The present algorithms (1) smooth the rough data, (2) interpolate missing data points, and (3) apply a number of criteria to evaluate and remove artifactual fixations. The input parameters (e.g. velocity threshold, interpolation latency) can be easily manually adapted to fit each participant. We assessed this method by testing its reliability in data from over 100 infants ranging from 3 to 12-month-old and comparing it with previous methods regarding expenditure of time and accuracy of detection. Results revealed that being able to adapt FD detection criteria and hand-code its outcome gives rise to more reliable and stable measures in infants.

◆ 53 **Factors affecting human gaze behavior: an analysis with complex natural scenes with superimposed object images**

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Humans perform frequent saccadic eye movements to collect visual information from the environment. To study human gaze behavior, we used natural scene images in with multiple visual objects were embedded. In order to quantify the conspicuousness of the objects, we defined a contrast index (CI) as the mean difference of RGB values of the object image and of the patch of background occluded by it. A low CI value leads to the visual impression of the object merging into the background, since typically also the surrounding of the patch is similar to the occluded patch (i.e., the structure of natural scenes is locally correlated). By manipulating the position and size of the object we controlled the conspicuousness of the objects and investigated the factors affecting the eye movements of human subjects freely viewing the composed images. As expected, high CI values led to a larger number of fixations on the objects as compared to objects of low CIs. However, also other factors influenced the gaze behaviors: a) objects near the center of the images were more often fixated than those in the periphery, and b) human faces attracted gaze more often than other objects.

◆ 54 **Eye-Fixation Related Potentials on Regions of Interest when viewing natural scenes**

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Eye-movements and EEG signals were recorded on participants viewing scenes under three tasks: free exploration (FE), categorization (indoor/outdoor) (CAT) or spatial organization that is to give the relative position between two objects (right/left) (SO). For each scene, some regions of interest (ROIs) and of non-interest (RONIs) were defined. ROIs were chosen as the most fixated areas during FE that moreover correspond to an object. RONIs were areas that were less fixated and did not correspond to an object. These ROIs and RONIs were used for FE and CAT. For SO, the ROIs corresponded to the objects of the question. Two kinds of ROI could be distinguished: the ROI useful for solving the task (SO) and the ROI not explicitly specified by the task (FE and CAT). We analyzed the EFRPs of two consecutive fixations that landed in ROIs and RONIs for the first time. A significant decrease of the P1 amplitude was observed on occipital electrodes for the second EFRPs when the fixations were inside ROIs. This decrease was observed both for ROIs explicitly specified by the task and for ROIs not linked with the task. No significant difference was observed between the first and the second EFRPs for RONIs.

◆ **Eye movements while viewing coarse and fine image information**

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Neurons in early visual regions show selectivity for different spatial frequencies (SF) and also many extrastriate areas show SF preferences. Yet, it is still unclear how we extract information from different SF in order to support high-level image recognition. Eye-movements are an integral part of normal visual behaviour and their characteristics may provide clues towards the sampling processes taking place during natural viewing. Here, observers freely viewed images of objects, faces, and natural scenes while their eye-movements were tracked. The original image and two manipulated versions were shown: either the low SF or high SF were kept intact, while the remaining frequencies were phase-scrambled. In line with coarse-to-fine models, we expected a bias towards relatively short-fixations and long-saccades when viewing low-SF-intact images (LSFi) and towards long-fixations and short-saccades for high-SF-intact images (HSFi). Contrary to this, fixations on LSFi were longer compared to those on HSFi. Saccade amplitude did overall not depend on SF scrambling. Fixations were biased towards the centre of LSFi, while on HSFi these were more distributed. This suggests the sampling of larger regions for low SF compared to high SF information. Our results have implications for the interpretation of fixations and saccades within the coarse-to-fine framework.

◆ **Influence of bottom-up and top-down processing on eye movement parameters in**

56 **horizontal scanning tasks**

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Horizontal gaze transfer in scanning tasks depends on cognitive and reflexive components of processing. Response to onset of peripheral stimulus is mostly reflexive. If stimulus consists of equally big dots arranged in horizontal lines, the importance of reflexive component in gaze transfer diminishes. Cognitive component can be increased by adding linguistic content to the stimulus and making the task similar to the scanning in reading. Monocular eye movements were recorded during different horizontal scanning tasks. Mean fixation times for individual participants and in group were shortest (250ms) in reading artificially constructed text where the angular distance between the first letters of the words were 1.9o. Longest mean fixation times (up to 720ms) were observed in gaze transfer between two equal dots located in 1.9o distance. By changing the amount of cognitive component in stimulus for scanning, the eye fixation times alternate between the shortest and longest limits. The average saccade amplitudes were largest in scanning two dots (1.9o). In sequential horizontal scanning task mean amplitude go down to 1.75o, simultaneously the increased number of small amplitude saccades (<1.60) was observed. This indicates that gaze transfer in scanning tasks can be directed by stimulus outline and adding linguistic meaning to it.

◆ **The influence of eye movements on contrast sensitivity and gain response in peripheral**

57 **vision**

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Saccadic eye movements dynamically alter visual processing: it has previously been shown that just prior to a saccade, low spatial frequencies are suppressed; and, for the saccade target, perceived contrast increases and visual crowding diminishes. The aim of this study was to more fully characterize the changes in visual perception immediately before the execution of a saccade, and to provide a functional account of these changes. We first measured the contrast sensitivity function at the goal of an impending saccade. Relative to when no eye movements were imminent, we found only partial support for active suppression of low spatial frequencies within 50 ms prior to saccade onset. Furthermore, we found no evidence of an enhancement of contrast sensitivity at any spatial frequency. We next quantified contrast discrimination thresholds during steady fixation and within 50 ms prior to a saccade. The resulting dipper functions overlapped across the range of pedestals tested (0% to 50% contrast), showing no appreciable changes in thresholds during saccade preparation. Thus, our data argue against the hypothesis that eye movements signals change response gain. Instead, our data suggest that previous demonstrations of enhanced perception at the saccade goal result from changes in higher levels of processing.

◆ **A binocular evaluation of pupil-size dependent deviation in measured gaze position**

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Camera-based eye trackers are the mainstay of eye movement research and countless practical applications of eye tracking. Recently, a significant impact of changes in pupil size on gaze position as measured by camera-based eye trackers has been reported [Wyatt 2010], and a first attempt at compensating for this drift was proposed (Drewes et. al. 2012). While ground truth was presented (Drewes et al. 2012), all previous studies used very few subjects to demonstrate this effect (5 and 2 respectively), and only monocular measurements were performed. In an attempt to improve understanding of the magnitude and population-wise distribution of the pupil-size dependent shift in reported gaze position, we present the first collection of binocular pupil drift measurements recorded from 20 subjects (SR Research Eyelink 1000, subjects were ethnic Han-Chinese). The pupil-size dependent shift varied greatly between subjects (0.6 to 4.4 degree, mean 2.4 degree), but also between the eyes of individual subjects (0.16 to 1.7 degree difference, mean difference 0.8 degree). We observed a wide range of drift directions. We demonstrate a method to partially compensate the pupil-based shift using separate calibrations in pupil-constricted and pupil-dilated conditions, and evaluate an improved method of calibration based on multiple different pupil-dilation conditions.

◆ **Systematic localisation errors of multiple objects after saccades and eye-blinks**

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Previous studies have detected systematic spatial compression when holding a representation of object locations in working memory (WM). Similarly, spatial compression also occurs when making a saccade immediately after stimulus presentation. This compression may be due to an interaction between the eye movement itself and the WM effects, since these representations are held in WM across saccades. The effect of eye blinks has not been examined in this context. To better understand the source of localisation errors, the current study compares the effects of saccades and blinks when reproducing the locations of 1–5 randomly-placed discs (masked), presented immediately prior to a saccade or blink; these results are compared to a control condition where observers simply hold the representation in WM for the same duration. This experiment allows us to further explore the role of visual WM in the perceptual phenomena related to saccadic compression and establish the effect of blinking on localisation. Our findings show that overall localisation errors are higher in saccade trials than in blink and control trials (where performance is identical). Furthermore, multiple objects are mislocalised together, indicating a uniform shift in object locations toward the saccade target as opposed to a compression of space.

◆ **Consistency of eye movements in MOT using horizontally flipped trials.**

60 F Dechterenko, J Lukavsky (Institute of Psychology, Academy of Sciences, Czech Republic; e-mail: filip.dechterenko@gmail.com)

When measuring intra-subject variability of eye movements, we often need to present trials repeatedly. In this experiment we studied, if we can use horizontally flipped trajectories of tracked objects and get similarly consistent eye trajectories. We presented each trial in two variants: L and R (horizontally flipped variant of L). Each variant was presented 6 times and each participant (N=26) was presented 5 different trials. Tracked objects moved in circular area with radius 15deg. We used Normalized scanpath saliency (NSS) metric for computing consistency of trajectories. Similarity of eye movements in within the same condition (NSS computed separately for L and R trials) was compared with mixed condition (NSS computed over trials sampled from both L and R trials). In the mixed condition we observed 14.7% decrease in eye movement consistency compared to the same condition and empirical baseline (similarity of individual eye movements across different trials). Those results are without any further corrections for gaze bias.

◆ **Eye movements in Multiple Object Tracking systematically lagging behind the scene content**

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In the current experiment I investigated whether the eye movements during Multiple Object Tracking (MOT) are based on the object positions in future or rather in past. Importantly this can be done without assumptions about specific participants' strategies. I recorded eye movements in MOT with 60 trials

(N=20). Participants tracked 4 of 8 objects for 10 seconds (speed 5deg/s). For every subject five trials were repeated four times each during the experiment and four times more in reversed direction. For each repeating trial I used Normalized Scanpath Saliency measure adapted for dynamic scenes to compare the eye movements between trials presented in forward and backward direction. I varied the latency between -250 ms (prediction) and +250 ms (lag) and looked for the local maximum (90% of comparisons had maxima within the inspected range). The systematical lag was present in each participant (mean 99ms; 95%CI 81- 116 ms). The results are discussed in the context of lagging and lag-reducing processes [Howard, et al. (2011). Vision Research, 51(17), 1907–1919.].

◆ **Saccades along the fast track**

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We explored the idea that high-speed self-motion can set the brain in a fast-track mode to enable short latency, visually guided (oculo) motor behavior. Visually guided reflexive saccades in a gap paradigm were executed during visual stimulation containing random-dot kinematogram (RDK) translational motion. Participants viewed a wide (60x40 deg.) display that contained 1500 moving white dots on dark background. In the experimental condition RDKs simulated a rollercoaster ride with the first 4 s of slow forward self motion and a 8-s period of rapid falling motion. Participants were instructed to execute pro-saccades to a left/right 15 deg. displacement of a central red fixation target. Participants also reported trial-wise whether they sensed illusory self motion (vection). Control conditions containing static dots, random dot motion, linear motion and a reversed upward rollercoaster condition were conducted to examine the specificity of possible effects on saccadic latency. Results indicate that in the experimental condition participants reliably experienced vection. During these falling sensations, participants executed saccades to the visual target with significantly lower latencies compared to other conditions. Our results suggest that self motion leads to quicker responses, suggesting the existence of the brain's fast track for sensory guided decision-making in dynamic contexts.

◆ **Control of saccadic eye movements: Impact of stimulus type on effects of flanker, flanker position and trial sequence**

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The experiment demonstrates the impact of stimulus type on the control of saccadic eye movements. More specifically, using the flanker paradigm, we examined whether stimulus type (arrows vs. letters) modulates effects of flanker and flanker position. Further, we assessed trial sequence effects and whether they are affected by stimulus type. A central target (a '<' or '>' in the arrow condition or an 'N' or 'X' in the letter condition) instructed a left- or rightward saccade. The target was accompanied by a congruent or incongruent flanker, shown to the left or right of the target. Considering the different processing required for arrows and letters, dissimilar flanker effects (FE), flanker position effects and trial sequence effects were predicted for arrows versus letters. The main findings demonstrated that (i) flanker effects were stronger for arrows than letters, (ii) flanker position more strongly modulated the flanker effect for letters than arrows, and (iii) trial sequence effects partly differed between the two stimulus types. We discuss these findings in the context of a more automatic and effortless processing of arrows, being overlearned symbols of direction, relative to letter stimuli.

POSTERS : BIOLOGICAL MOTION, PERCEPTION AND ACTION

◆ **Motion coherence and biological motion perception**

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Sensitivity to coherent motion is often contrasted with performance in biological motion and global form tasks to assess differences in motion and form processing, which are related to the dorsal and ventral visual streams, respectively. Here, we used point-light walkers to investigate how the perception of local motion and form information in biological motion stimuli is related to sensitivity to coherent motion, which up to now has been relatively unexplored. We asked participants to perform a biological motion direction discrimination task for normal walkers that contain both local motion and global form information, scrambled walkers that primarily contain local motion information and random-position walkers that primarily contain global form information. We determined motion coherence thresholds for

each observer and correlated performance for point-light walker discrimination with individual motion coherence thresholds. High sensitivity to coherent motion correlated with increased performance for normal, and, to a lesser extent, also with random-position point-light walkers. Interestingly, there was no correlation between performance for scrambled walkers and sensitivity to coherent motion. These results support the hypothesis that sensitivity to motion coherence is not necessarily confined to dorsal stream functioning.

◆ **Matching Biological Motion at Extreme Distances**

65 I M Thornton, Z Wootton, P Pedmanson (Psychology Department, Swansea University, United Kingdom; e-mail: i.m.thornton@swansea.ac.uk)

How far away can an observer be positioned and still decide what a distant actor is doing? We conducted a laboratory study in which we systematically varied the apparent distance of point-light figures relative to a fixed viewing position. Two flanking point-light figures were kept at a constant apparent distance of 15 meters from the observer, subtending approximately 6.7° in height. The apparent distance of a central target figure was varied between 15 and 1000 meters by systematically scaling its size. On each trial, the two flankers performed different actions (e.g., walk, sweep, chop, wave), and were randomly rotated in depth. The target figure always copied the action of one flanker, but was out of phase and had an independent depth orientation. The task was simply to indicate whether the target action matched the left or right flanker. Matching accuracy for dynamic, but not static, figures remained above chance even at the most extreme distances where the entire figure subtended only 0.1° in height. Our data also suggest that increasing distance leads to a transition from fast, efficient processing, to slower, more effortful decision-making, an idea that is absent from existing models of biological motion processing.

◆ **Rowing, Expertise and Biological Motion**

66 S Liebert, U Strandenes Alvaer, I M Thornton (Psychology Department, Swansea University, United Kingdom; e-mail: i.m.thornton@swansea.ac.uk)

The majority of biological motion studies have used point-light walkers as stimuli. In the present work we examined rowing as another periodic movement pattern that might provide a useful context for studying biological motion. We recorded motion capture data from 12 actors (6 male, 6 female) who varied in their level of rowing experience. Stroke rate was normalised at 16 strokes per minute, and we extracted one "light" pressure and one "firm" pressure stroke from each rower to serve as experimental stimuli. A custom iPad application was written to present looped, point-light versions of each stroke together with three rating sliders. We asked observers to rate each stroke on three dimensions: actor gender, actor expertise and stroke effort. A total of 43 participants took part in this rating experiment. Twenty-one were currently active rowers and twenty-two were non-rowers. On all three dimensions participant responses could be used to distinguish between the underlying action categories. The experienced rowers outperformed the non-rowers only on the perception of stroke effort. These results demonstrate that information can be extracted from point-light rowing patterns and provides further evidence that visual and/or motor expertise can modulate performance.

◆ **Biological movements realized by point-light walkers and stylized eye movements in a response priming paradigm**

67 D Eckert, C Bermeitinger (Institute for Psychology, University of Hildesheim, Germany; e-mail: eckertd@uni-hildesheim.de)

Moving stimuli represent salient stimuli which are able, for example, to guide attention and eye movements fast and unintentionally. Until now, there are only few response priming experiments using moving stimuli. Response priming refers to the finding that the response to a target stimulus that follows a prime stimulus is influenced by the prime stimulus. Typically, there are faster Responses when prime and target require the same response (i.e., congruent trials) compared to different responses (i.e., incongruent trials). We showed in own studies that this pattern is reversed with stimulus onset asynchronies (SOAs) above 200 ms when we used moving stimuli as primes. In the current experiments, we conducted several response priming studies with biological moving primes (point-light walker and stylized eye movements) and static arrow targets and varied the stimulus onset asynchrony (SOA) between prime and target. Most interesting, with biological movements (especially point-light walkers) we found huge positive priming effects for SOAs of 180 and 360 ms, and smaller but still positive priming effects with rather long SOAs of 800 and 1200 ms. Results were discussed according to different theories on negative compatibility effects and theories on perception and processing of biological motions.

◆ **The impact of vision and tendon vibration on goal-directed movements**

68 A Lavrysen, F Van Halewyck, W F Helsen (FaBeR Centre for Motor Control and Neuroplasticity, University of Leuven (KU Leuven), Belgium; e-mail: ann.lavrysen@faber.kuleuven.be)

Aiming bias is influenced by the type of visual information when aiming to a Müller-Lyer illusion (Lavrysen et al, 2006, Experimental Brain Research 174(3), 544-554). This demonstrates a tight coupling between visual and manual information for movement planning and online control. Tendon vibration (TV) typically induces an undershoot of the target at the antagonistic side of the muscles vibrated. In this study we investigated whether visual information affects the proprioceptive illusion effect caused by TV. Local TV was applied to the wrist extensor muscles while making cyclical aiming movements. The results showed that TV induced an illusory reduction of almost 25% in movement amplitude, independent of the onset of the vibration (peak flexion or peak extension). Interestingly, neither eye movements nor eye-hand coordination were affected by tendon TV. However, vision condition (making saccades vs. fixating; targets present vs. absent) did mediate the vibration effect. Specifically, the effect increased when the targets were removed and when fixating. Apparently, making use of unperturbed retinal and extraretinal information helps to reduce the proprioceptive illusion of local TV. These results confirm a tight link between saccadic and manual perception and action.

◆ **Movement drift following visual occlusion of the hand and target**

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Without hand vision, reaches not only become more variable, but they also systematically drift away from their original target. This has sometimes been attributed to a deterioration of the proprioceptive estimate of the hand without recalibration by vision. Here we test the hypothesis that drift is due to optimal integration of misaligned sensory estimates, rather than any decay or shift in the proprioceptive estimate of the hand [Smeets et al, 2006, PNAS, 103(49), 18781-18786]. We examined movement drift over the course of 40 back-and-forth movements when (1) vision of the hand was occluded, (2) vision of the targets was occluded, and (3) vision of the hand and targets was occluded. On some trials, we introduced direct proprioceptive information about the targets (the non-dominant hand beneath the reaching surface) to increase the reliability of the proprioceptive estimate of the target. We observed equal drift magnitude in the no-target and no-hand vision conditions, and the most drift when neither hand nor target was visible. Presence of a proprioceptive target influenced the direction of drift, but did not influence the magnitude of drift. Our results are only partially consistent with Smeets et al's model.

◆ **Is there an uncertainty principle in interceptive timing?**

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In physics the uncertainty principle asserts a limit to the precision with which position and momentum can be known simultaneously. Intercepting moving objects at given positions within a temporal window also requires precision in predicting future positions (to avoid sensorimotor delays) and knowing the temporal error that we can afford based on target velocity. In two tasks subjects had to synchronise a key press with moving Gabors (0.9 c/deg) crossing a designated position at different speeds or intercept the Gabors by controlling a cursor. To test the reliance on perceived position I induced position shifts (forward/backwards) by adding local drift (same/opposite) to the global displacement. The perceived position accounted for the initiation of the interception but not its end point. This was consistent with subjects monitoring the position to start the action but relying on velocity to perform the motor movement. Interestingly, when subjects only had a single moment (synchronisation task) the responses reflected a compromise between position and velocity. This trade-off resulted in a U-shape of the combined (position and temporal) variability that was only present in the synchronisation task. Single time responses reflect then an uncertainty principle when minimising temporal and position errors.

◆ **Self-splitting objects in rapid visuomotor processing: Behavioral evidence from response force measures**

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We studied the processing of self-splitting objects in the time-course of response force measures. We simultaneously presented two central prime triangles (one inverted). Participants responded to peripheral target triangles (one inverted) that followed the primes with varying stimulus onset asynchronies (SOA). The participant was asked to indicate the position of the (inverted) target triangle that was either on the

same (consistent trials) or other side (inconsistent trials) as the (inverted) prime triangle. Primes were occluded by zero to three overlapping shapes such that the visual system was exceedingly challenged in extracting the triangle shapes. We obtained priming effects in response time and response force between consistent and inconsistent trials that were modulated by the number of occluding shapes. We analyze our results with respect to behavioral rapid-chase criteria that test for sequential (feedforward) processing in online measures of motor control. Our findings show that objects are split into their components early on in the time course of visual processing. However, this rapid visuomotor processing of self-splitting objects is not based on pure feedforward processes.

◆ **Influence of object weight and movement distance on grasp point selection**

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To effectively manipulate objects we need to choose appropriate grasp points. We brought two possible determinants of grasp point selection into conflict: minimizing torque versus minimizing movement costs. 21 right-handed subjects reached to grasp objects (10x3x1cm) of different mass from different distances to its left or right. Torque minimization predicts a grasp near the object center. Minimizing movement costs predicts a grasp nearer to where the movement started. As expected, the tendency to grasp off-center was larger for light objects, for which this produces less torque. However, the grasp axis was shifted to the right of the center, irrespective of where the movement started. The rightward bias was reduced when the required precision was increased in a second experiment (N=19) by having subjects balance the object on a small cylinder after grasping. Starting the movement above the object eliminated the bias, as did grasping with the left hand. In the latter case subjects tended to grasp the object to the left of its center. We conclude that grasp points are near the center to ensure stability, but tend towards the side of the acting hand to improve visibility.

◆ **Comparison of Causal Inference Models for Agency attribution in goal-directed actions**

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Perception of own actions is influenced by visual information and predictions from internal forward models[1]. Integrating these sources depends on associating visual consequences with one's own action (sense of agency) or with unrelated changes in the external world[2]. Attribution of percepts to consequences of own actions should rely on the consistency between predicted and actual visual signals. We investigate whether the data supports binary [3] or continuous[4] attribution. Methods: To examine this question, we used a virtual-reality setup to manipulate the consistency between pointing movements and their visual consequences and investigated the influence of this manipulation on self-action perception. In previous work[3] we showed that a causal inference model, assuming a binary latent agency variable, accounted for the empirical agency data. New models assuming continuous attribution of visual feedback to own action are presented and their prediction performance evaluated and compared to the binary model[2]. Results and Conclusion: The models correctly predict empirical agency ratings. We discuss their performance, applying methods for model comparison. [1]Wolpert et al.,Science,269,1995. [2]Körding et al.,PLoS ONE,2(9),2007. [3]Beck et al.,JVis,11(11):955,2011. [4]Wilke et al.,PLoS ONE,8(1):e54925,2013.

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◆ **Observing errors vs. expertise during surgical training**

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Several recent findings have demonstrated that the observation of a visuomotor task leads to more rapid learning of that skill (Mattar & Gribble, 2005). Watching the performance of others is an important part

of surgical training, with medical students routinely observing expert surgeons to learn new procedures. Recent work, however, suggests that errors are crucial for observational learning (Brown et al., 2012; Buckingham et al., under review). We examined medical students' performance in a surgical training task on a virtual reality simulator. The trainees then watched a video of either a novice individual or an expert surgeon performing the surgical task on the simulator. After watching the video, the medical students then performed the simulator training task immediately after, and one week later. Individuals who watched the error-laden novice performance were significantly better than those who watched the error-free expert surgeon's performance when they returned one week later, across a number of metrics. These findings suggest that observing errors may be crucial for the rapid learning of a wide variety of visuomotor skills, and suggest error-based learning should feature prominently in early training of complex skills.

◆ **Expert visual diagnostics: systematic convergence or random approach?**

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Horses can not communicate symptoms through language, so veterinarians have to detect complaints by other means. 'Lameness' is the most common problem in horses. In order to determine the presence of lameness and locate the affected leg, a veterinarian will watch for asymmetry of movement. Unfortunately, visual examination is inherently prone to disagreement particularly for subtle lameness, confounding reliable diagnosis. Especially for trot on the circle there is currently no accepted evaluation protocol. Hence, we wondered whether expert veterinarians converge on a similar visual assessment strategy in the absence of strict rules. An eyetracker (Tobii T60) recorded gaze data for 24 experts in equine lameness examination. Participants evaluated videos of 14 horses trotting in various conditions. Gaze data were manually mapped onto 16 body regions of each horse. Results showed pronounced variation across experts in the cumulative percentage viewing time allocated to each body region. Further, there was considerable variation in the number of regional revisits, the frequency of regional switches and the time rested per visit. No discernible systematic scanning approach was found, although individuals showed preferences for certain scan paths. We conclude that the absence of diagnostic rules can lead to development of greatly differing approaches.

◆ **Short-term adaptation to stimulus statistics requires behavioral relevance**

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Several recent studies have shown that short-term experience is used to adaptively improve perceptual estimates and map them to motor responses. Examples are visual distance estimation or manual reaching to visual targets. The underlying mechanism can be described as dynamic Bayesian updating of a prior distribution of the stimuli that is integrated with the current sensory input to form an improved estimate of the external stimulus. Notably, feedback on the actual performance is not required for this type of learning of the stimulus statistics. However, since the brain is normally confronted with a multitude of possible stimuli, this raises the question whether just experiencing the stimuli is sufficient to learn about them. Here we investigated whether it makes a difference for learning from experience whether or not participants are required to behaviorally react to a given stimulus. Our results show that on average participants only adapted to the stimulus statistics, if they had to reproduce the stimuli. Thus, sensory experience itself was not sufficient to learn the underlying stimulus statistics. Instead, behavioral relevance, i.e., whether or not to act upon a stimulus, determined whether the stimulus was used for short-term adaptation.

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◆ **Sequential learning of the relationship between action and visual feedback using a rolling**

77 **ball game with conflicting rotational transformations on a tablet device**

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How do humans learn the relationship between their actions and visual feedback when operating an object under a physically unpredictable model? Using a simple rolling ball game on a tablet device, we

developed a system that can produce novel action–feedback relationships for participants by changing the ball-rolling direction. Participants operated the ball with specific rotation transformation from a natural gravity-based direction to hit a static target. Learning was evaluated by hit count and entropy estimates from x- and y-axis acceleration history. Results were separable into two distinct categories: one for learning action–feedback relationships similar to those we already have, such as 10° rotation, and another for different action–feedback relationships, such as 90° and greater rotation. Our findings support the view that participants were able to learn novel action–feedback relationships separate from already established relationships or their inner model and that tablet manipulation entropy is a good indicator to show this. Also, we have shown that our application is a handy tool to investigate the relationship between human actions and visual feedback.

◆ **Non-Linear Extrapersonal Space: An Additional Twist in Prism Adaptation**

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Prisms can shift the visual world laterally. In experiments, subjects usually have to point to a central target, seen - due to the prism shift - in the near periphery of the visual field. Pointing errors decrease due to neuronal shifts: adapted, subjects either perceive the peripheral visual direction as straight ahead or change their arm proprioception for straight-ahead towards the perceived target location. Hence, visual and haptic adaptation involve opposite directions from different starting points, but are usually supposed to add linearly due to a linear spatial representation. We tested this assumption by asking subjects to point to targets both centrally and in peripheral space without visual feedback, both before and after prism adaptation. Without visual feedback: a) subjects consistently underestimate the amount of eccentricity, i.e. perform movements too close to the center even before prism adaptation; b) over the course of ten movements these movements shift even closer to the center; c) prism adaptation increases this effect: observers adapt to the position of a target during prism adaptation but underestimate the eccentricity of peripheral targets even more than before adaptation. We conjecture that the adaptation process underlying prism adaptation changes space representation in a complex and "conservative" way.

◆ **Incomplete Prism Adaptation in Throwing**

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Subjects wearing prisms adapt to the resulting shift of the optical image within a few movements according to common knowledge. We scrutinized this notion and found that prism adaptation is incomplete even after more than one hundred throws. In several set-ups we tested more than 50 subjects with prisms shifting the visual image by 17 degrees either to the right or to the left. Overhead throwing movements employed softballs towards a Velcro plated screen. Ball position was recorded by means of a camera connected to a computer. In addition we tested pointing movements performed underneath a table, with terminal visual feedback. Finger trajectories were recorded by an ultrasound device (Zebris). Deviation from target decreased with increasing number of movements, almost following an exponential function. While deviations from target did not differ significantly from zero after 100 pointing movements, ball positions still deviated significantly from the target in the throwing experiment. After removal of the prisms, typical aftereffects in the opposite direction emerged in both experiments. We interpret this incomplete adaptation exclusively for throwing as indicating different mechanisms for prism adaptation in pointing versus throwing movements, possibly reflecting basic differences between the neuronal representation of near versus farther extrapersonal space.

◆ **Imitative learning of piano-playing-like movement facilitated by body ownership illusion**

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Imitative learning is commonly observed in various motor learning, such as tool use, sports, and musical instrument playing. To perform imitative learning, a learner needs to first solve self-other correspondence problem, then calculate motor commands that appropriately reproduce the observed motion. Human adults and children seem to be somehow able to effectively perform this computationally difficult process, but the underlying mechanism is unclear. In this study, we have found that imitative motor learning of sequencial finger movement similar to piano playing can be facilitated when the learner is under body ownership transfer illusion. We presented a computer-generated animation of a hand performing the movement as the instructor, and induced the illusion by visuo-tactile stimulation using a moving computer-generated cone-shaped object and a vibration motor. We tested two conditions, synchronized

and unsynchronized visuo-tactile stimulation, and found that the learning was significantly improved when synchronized stimluation was given. The result suggests existence of a common mechanism share by both perception of body ownership and imitative motor learning.

◆ **Does looking between the legs elongate or shorten perceived distance - comparing two tasks**

81 O N Toskovic (Laboratory for experimental psychology, Faculty of Philosophy, University of Belgrade, Serbia; e-mail: otoskovi@gmail.com)

Higashiyama used a verbal judgement task and showed that distances observed between the legs are perceived as shorter than distances viewed from an upright position. Using a distance matching task, we showed that distances observed between the legs are perceived as longer, but we didn't control for retinal image orientation. The aim of the present research was to compare the verbal judgement and the distance matching tasks, with constant retinal image orientation. The experiment was performed in a dark room, without retinal image orientation change. The first task for the 14 participants was to equalize the distances of two luminous stimuli, one of which was placed in front of them, and the other one behind, with three distances, 1m, 3m and 5m. The second task was to give verbal judgements for stimuli distances, one observed while standing, and the other while looking between the legs. Results for the first task showed significant effects of body position, distance of standard, and their interaction. Results for the second task showed significant effects of body position, distance of standard, but no significant interaction. In both tasks distances viewed between the legs were perceived as larger than distances viewed from an upright position.

◆ **The unbearable lightness of perceiving: The effect of load on perceived distance**

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Researchers demonstrated that human perception of both distance and effort is anisotropic: people perceive distances and invested effort toward the zenith as greater than those observed in opposite direction. It is hypothesized that action that confronts gravity takes more effort than action in opposite direction, and that perceiving distances as larger is in the funcion of succsessful action (by overestimating distances at direction where action confronts gravity, we engage more effort and preform succsessful action). Since findings suggest that effort invested in action is related to distance perception, we investigated whether perception of distance can change with systematic change of effort. The sample consisted of 14 participants, and two weights (1kg and 2kg) were used in order to vary effort invested in action. The participants' task was to equalize distances of the lamps (left and right, at three possible distances – 1m, 3m, 5m), when wearing different loads (none, 1kg or 2kg). However, results showed no effect of the load: estimations of the distance were the same regardless of the difference in invested effort. These results raised questions both about amount of effort relevant for the effect and its nature (shot or long term accommodation of the system).

◆ **Visual distractor interference on foot movements during walking**

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Distractor interference is a well-studied phenomenon in vision-and-action: when selecting a visual target in the environment to act upon, a distractor in close proximity to the movement trajectory will impact on the actual movement – be it a hand or an eye-movement. Here we investigated whether distractor interference also impacts on the visually-guided action of the lower limbs. In a "stepping stone" walking task, twenty-five participants stepped on predefined target elements projected onto the floor in the presence or absence of visually easily distinguishable distractors. As measured with 3D motion capture, participants slowed down when distractors were present ($t(7256)=7.265$, $p<.0001$) and their stepping accuracy (landing position on target) was reduced ($t(7246)=1.952$, $p=0.05$). Comparing foot movement trajectories of similar stepping speed for distractor-present and distractor-absent trials also revealed that trajectories for the former were significantly more curved than those for the latter (for 21 out of 25 of the participants), in direct analogy to saccade curvature or hand movement curvature. Results will be discussed with respect to current biomechanical models and possible implications for balance loss and falls risk.

◆ **The role of visual attention in movement planning and control**

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Previous research has suggested that movement planning (requiring ventral stream processing) but not movement control (mediated by the dorsal stream) is vulnerable to dual-task interference from a simultaneously executed - attention demanding - perceptual task [Liu, Chua & Enns, 2008, Experimental Brain Research, 185, 709-717]. This finding has led to the suggestion that the dorsal (action) and ventral (perception) streams might be controlled by separate attentional mechanisms. In this study, we designed a dual-task paradigm in which participants had to perform a pointing movement towards a target presented in their visual periphery whilst at the same time identifying a perceptual target presented in central vision. In 25% of all trials the position of the pointing target perturbed during movement onset requiring the fast online-correction of movement trajectory. Reaction times (RT) and endpoint accuracy in the dual-task condition were compared to performance in a baseline condition in which no perceptual target had to be identified. Our results show dual-task interference effects in both movement planning (indicated by prolonged RTs) and movement control (indicated by reduced endpoint accuracy and less efficient online-corrections after perturbation). These findings provide further evidence that perception and action share the same central processing resources.

◆ **Adaptation to actions outside the focus of attention – evidence for automatic "mirror"**

85 **network activation?**

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This fMRI study investigated whether areas of the action-observation network are activated when participants are engaged in a task that does not require attention to be paid to the action. Using a repetition suppression paradigm we presented objects that had to be categorized either as garage or kitchen items along with two-frame hand "actions". In the first frame a hand was presented in a neutral position to the side of the object; in the second frame the hand was almost touching the object either in an action appropriate or inappropriate position. We hypothesized that, in line with behavioural findings, appropriate actions are more attention-grabbing and therefore more likely to be perceived/processed as actions. Therefore, we should see a larger repetition suppression effect for repeated appropriate compared to repeated inappropriate actions in areas that are activated during action observation. A whole-brain random effects analysis for this interaction revealed significant activations in canonical parietal and frontal "mirror" regions. This pattern was also found in individually-defined action- and body-selective ROIs; however these effects failed to reach significance. Overall, our results provide preliminary evidence for activation of "mirror" areas that discriminate appropriate from inappropriate actions even when they are unattended.

◆ **Active control enhances anticipatory motion extrapolation during multiple object tracking**

86 M P Leenders, A Koning, R van Lier (Donders Institute, Radboud University Nijmegen, Netherlands; e-mail: m.leenders@donders.ru.nl)

We have used a new, interactive variant of the multiple-object tracking (MOT) task combined with a probe-detection task to study the distribution of attention across a display with several moving targets. Recently, it has been found that probes (small, transient dots) presented ahead of to-be-tracked targets are detected better than probes in the wake of such targets, although imminent changes in direction, such as upcoming bounces, are not taken into account [Atsma, Koning, and van Lier, 2012, Journal of Vision, 12(13):1, 1 – 11]. Here, we investigated this further by creating a 'pong-like' MOT-task, in which half of the participants actively moved a pong-paddle around in order to hit the targets; the other participants observed recorded trials of participants in the active condition. By comparing probe-detection rates of active participants with that of the passive observers, we found that when participants actively changed the direction of targets by acting upon them, attention was also deployed along a post-bounce path. In the passive condition there was an advantage for linear extrapolation even when the targets bounced against the paddle. We conclude that active control enhances anticipatory motion extrapolation.

◆ **Effect of travel speed on visual control of steering toward a goal**

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We systematically examined the effect of travel speed on the control of steering toward a goal. The display (113°H×89°V) simulated a participant traveling at 2m/s, 8m/s, or 15m/s over a textured ground plane. Participants used a joystick to control the curvature of their path of forward travel to steer toward a target. Across 16 participants, when target egocentric direction cue was unavailable thus participants had to rely on optic flow alone for steering, participants steered to align their heading but not their path of forward travel with the target at all travel speeds tested. Furthermore, the mean last sec heading error and the mean steering delay decreased as travel speed increased. When target egocentric direction was available for steering but was offset from the heading specified by optic flow, participants' steering was affected by the offset target egocentric direction at all travel speeds tested. Furthermore, the last sec heading error decreased but the mean steering delay increased as travel speed increased. We conclude that while people are increasingly more accurate and efficient in using optic flow for steering when travel speed increases, high-speed travel does not affect the type of visual strategy used for the control of steering toward a goal.

◆ **I like to move it (move it): EEG Correlates of Mobile Spatial Navigation**

88 B Ehinger, P Fischer, A L Gert, L Kaufhold, F Weber, M Marchante Fernandez, G Pipa, P König (Institute of Cognitive Science, University of Osnabrueck, Germany; e-mail: behinger@uos.de)

In everyday life navigation, active movement generates visual, vestibular and kinesthetic information. Yet, studies of human navigation commonly employ stationary setups with obvious consequences on vestibular and kinesthetic feedback. Here, we demonstrate a fully immersive virtual reality with systematic control of vestibular and kinesthetic information combined with high density mobile EEG to investigate cortical processing in a spatial navigation task. The experiment is based on a modified triangle completion task: Participants traversed one leg of a triangle, did an on-the-spot-turn and continued along the second leg. They then had to point back to their starting position. We employed a 2x2 intra subject design, manipulating vestibular and kinesthetic information. The 128 Electrode EEG-data of all subjects (n=5) were analyzed by clustering blind source separated independent components (ICs) dipoles with their respective event-related spectral perturbations (ERSP). We select five IC-clusters, partially replicating earlier studies (e.g. Gramann et. al., 2010, JoCN, 22:12) in occipital, parietal and premotor areas. Specific alpha desynchronisation of ERSPs during the turn can be related to increased demand concerning visuo-attentional processing. Cluster-specific modulations of condition are present, which are potentially related to the additional vestibular and kinesthetic information provided.

◆ **Oculomotor feedback on visually guided movement control in putting using Cued**

89 **Retrospective Commentary**

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First-person perspective video has been shown to promote improvement in putting technique [Smith and Holmes, 2004, Journal of Sport and Excercise Psychology, 26, 385-396] however such videos introduce parallax error between shoulder-mounted camera and the true cyclopean view. We used lightweight head mounted eye-tracking equipment to eliminate parallax and record an overlaid gaze cursor at 30Hz sampling rate for the entire putting stroke. After putting, we also recorded a cued retrospective commentaries (CRC) at 25% of video playback speed to allow verbal annotation to the visual imagery stimulus. We present a training protocol based both on video exposure to expert real time third person and first person perspective CRC 're'view. Pre-training novice eye-movement recordings revealed anticipatory saccades to target at the onset of the downswing of the stroke, post-training recordings show increased duration of 'quiet eye' steady fixation during downswing. Gaze CRC extends the scope of imagery techniques to include multiple perspectives and feedback on oculomotor behaviour during stroke. CRC also enables more detailed testing of the cause of aiming errors reported in both novice and experiences putters (Johnston et al. 2003, Perception 32(9), 1151-1154). (Crundall is employed by Tracksys Ltd).

◆ **Comparison of reactive and cognitive search strategies**

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Reactive searching is controlled by current perceptions that activate pre-programmed movements: e.g. pheromone-seeking male moths surge upwind towards the source whenever detecting an odor while crosswind casting otherwise [Kaissling, 1997, in: Orientation and Communication in Arthropods, M Lehrer, Birkhaeuser Verlag, Basel; Martinez et al, 2013, Plos One, accepted]. Similarly, a salient visual stimulus evokes a reflexive saccade towards it. Cognitive searching uses Bayesian inference to build a spatial probability map based on the gathered information. Cognitive strategies were applied for visual [Najemnik & Geisler, 2008, J Vision 8(3):1] and olfactory [Infotaxis: Vergassola et al, 2007, Nature 445:406] searches. Comparing reactive and cognitive search strategies in a confined spatial region using a pheromone-seeking cyborg we find that computationally less expensive reactive strategies are nonetheless quite efficient. Cognitive olfactory search trajectories are simulated using Infotaxis. A variation thereof with a localized blinking light as visual stimulus is suggested to represent search trajectories of eye movements. Assuming that cognitive strategies in both modalities are optimized with respect to maximizing the information gain, we investigate the differences for visual versus olfactory stimulation.

◆ **Landmarks Reduce But Not Eliminate Gaze-Dependent Errors in Memory-Guided Reaching**

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Previous studies suggest that the brain codes and updates the locations of remembered visual targets relative to gaze. In an earlier study, we showed that this was true for both immediate and delayed movements, at least when no other visual cues are present [Fiehler, Schütz and Henriques, 2011, Vision Research, 51(8), 890-897]. The present study investigated whether additional cues from stable visual landmarks influence gaze-dependent spatial updating of reach targets. If the brain uses a purely gaze-dependent representation to encode and update remembered target locations, we expect no differences in gaze-dependent reaching errors with or without landmarks. However, if an allocentric or a combination of both allocentric and gaze-dependent representations is used, we expect reduced or no gaze-dependent errors. Subjects foveated visual targets, then shifted gaze to an eccentric fixation position before they reached for the remembered target either immediately or after a delay of up to 12 seconds. In the landmark condition, vertical light tubes to both sides of the stimulus display served as landmarks. Reach errors varied with current gaze direction regardless of landmark availability and delay. With landmarks present, the gaze-dependent pattern was significantly reduced, suggesting a combination of ego- and allocentric representations.

◆ **Movement leads to gaze-dependent spatial coding of somatosensory reach targets**

92 S Mueller, K Fiehler (Experimental Psychology, Justus-Liebig-University Giessen, Germany; e-mail: stefanie.mueller@psychol.uni-giessen.de)

Reaching towards objects requires that target and effector are coded in a common reference frame. Previous research consistently showed that remembered visual targets are represented relative to gaze [Henriques et al, 1998, The Journal of Neuroscience, 18(4), 1583-1594]. However, the reference frame used for somatosensory reach targets appears to be less clear. While some behavioral studies investigating reaches to proprioceptive targets found evidence for gaze-dependent coding, a neuroimaging study reported body-centered coding of proprioceptive stimuli. We examined the role of movement of the limb on which the targets are applied (the target effector) on spatial coding of reach targets. Subjects fixated an eccentric location while a touch was delivered to the target effector and then reached to the remembered location of the touch. We found that reach errors were unaffected by gaze when the target effector was kept stationary; however, they significantly varied with gaze when the target effector was actively moved before reaching. Introducing a gaze shift between target presentation and reaching also resulted in gaze-dependent errors which were further increased when combined with a moved target effector. In sum, our results suggest that movement of the target effector or gaze initiates gaze-dependent spatial coding of somatosensory reach targets.

◆ **Where is the Ego in Egocentric Representation?**

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Egocentric spatial representations have the body as their point of reference. Bodies, however, are not points, but extended objects with distinct parts which can move independently. Where on the body is the origin of the egocentric reference frame? We investigated this question by dissociating the role of the head and torso in determining simple deictic spatial judgments of whether an object is to someone's right or to their left. Birds-eye images of a person were shown on a monitor with the head turned 45° to the right or left. On each trial, a ball appeared at one of three distances and participants judged whether the ball was to the person's left or to their right. The contribution of angular deviation from both the head and the torso to judgments was quantified using multiple regression. Both the head and torso made independent contributions to judgments, indicating that there is no single egocentric reference frame for deictic judgments. However, the contribution of the torso was significantly larger than that of the head, demonstrating that judgments are not simply an average of each reference frame.

◆ **The method of testing the ability of allocentric cognitive maps acquisition**

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The aim of our study was to develop the method for testing the ability of allocentric cognitive maps (ACM) acquisition. As allocentric cognitive maps are learned through egocentric views during a wayfinding in a real-world environment, we created the virtual environment to stimulate an observer-centred frame of reference and the method to test its ACM reference. A virtual maze was created and presented using the CAVE system. It consisted of 12 rooms having different sizes, the same wall textures and with no any landmarks. Thirty nine observers (age range 18—22) were tested. The task was to go through all rooms and remember their arrangement. Then to test acquired ACM they should use the special interface consisted of rectangles and door symbols which the participants could locate and vary in accordance with her/his acquired ACM. The accuracy of learned ACM was estimated as complex characteristics including the number of correctly located rooms/doors, their mutual arrangement and the number of repetitions of passing routes. The results showed that the main difficulties in processes of ACM acquisition were connected with errors in the representation of mutual room arrangement.
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◆ **Spatial Models in Impossible Worlds**

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A long-standing question exists regarding the nature of mental representations of scenes. Many researchers assume a Euclidean map-like representation, yet some studies point to alternate formats such as graphs or some hybrid model involving graphs and viewpoints. One past study employed an "impossible-worlds" paradigm, with results arguing against the existence of a purely Euclidean representation [Zetzsche et al., 2009, Spatial Vision, 22(5), 409-424]. The results raise complex questions regarding the possibility of different representations being employed depending on the circumstances surrounding scene exploration and recall. A pair of studies was conducted to explore these questions. Results indicate that performance using the locomotion interface does impact shortest-path judgments, but only when the task involves choices of greater difficulty that require a participant to "complete the loop," such that each candidate path must be mentally traversed. Further, results point to possible differences depending on the shape of the scene. These findings spur additional questions regarding the influence of scene characteristics, a user's competence using the interface, and task difficulty on the construction and utilization of mental maps.

◆ **Updating visual direction in real and virtual scenes.**

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As humans move from one location to another, the visual direction of objects around them changes continuously. We investigated the information required to do this accurately. Participants viewed a real or virtual scene containing a prominent target then walked to a second location in the room (or, in one instance in virtual reality, were teleported there). From here, they pointed back to the target. One virtual

scene closely mimicked the real scene, while in another sparse condition the target and corners of the room were replaced by very long thin poles in an otherwise black scene. In this case, there was no ground plane and information about the distance of the poles could only be derived from the changing angle between them. We found that the richness of the scene made a negligible difference to pointing precision. On the other hand, visual information presented during walking had a beneficial effect on pointing precision even when the target was not visible during this phase. These data will help constrain models of how humans point at invisible targets from unvisited locations, which currently present a challenge to view-based models of spatial representation.

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◆ 97 **Face selective areas in the human ventral stream exhibit a preference for 3/4 views in the fovea and periphery**

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The ability to recognize faces irrespective of viewpoint is crucial for our everyday behavior and social interaction. However, not all viewpoints allow for equally good recognition and generalization performance, an effect known as the ¾-view advantage [Krouse, 1981, Journal of Applied Psychology, 66, 651-654]. Here, we use fMRI BOLD to investigate whether face-selective areas in the ventral stream exhibit a similar preference for ¾-views by measuring the responses of OFA and FFA in a 3x3 design including viewing angle (left and right ¾- and frontal view) and position (foveal, left- and right peripheral positions). In every stimulus position, OFA and FFA responded more strongly to the presentation of ¾-views, as compared to a front-on view. Interestingly, however, we find the effect to be opposite for ipsi- and contralateral stimulus presentations. Whereas the right OFA and FFA responded strongest to a right-facing view in the left visual field, a left-facing view was preferred in the fovea and right, ipsilateral visual field. No such interaction was found in V1 and LOC. This rules out potential low-level explanations of the effect and demonstrates a correlation of OFA and FFA responsiveness to the psychophysical ¾ view advantage.

◆ 98 **Independent face- and body-selective response patterns in human fusiform gyrus during whole-person perception**

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Previous neuroimaging studies that investigated neural responses to (bodiless) faces and (headless) bodies have reported overlapping face- and body-selective brain regions in right fusiform gyrus (FG). In daily life, however, faces and bodies are typically perceived together and integrated into a whole person. This raises the question of how neural activity in response to a whole person relates to activity evoked by the same face and body presented in isolation. The present study used fMRI to model the relation between FG responses to faces, bodies, and whole persons. We found that responses in right FG were significantly higher to persons than to bodies and faces shown in isolation, even in category-specific regions that were defined by their selectivity for faces (FFA) or bodies (FBA). Using multi-voxel pattern analysis, we then modeled person-evoked response patterns in right FG through a linear combination of face- and body-evoked response patterns. We found that these synthetic patterns were able to accurately approximate the response patterns to persons, with face and body patterns each adding unique information to the response patterns evoked by whole-person stimuli. Our results suggest that whole-person responses in FG primarily arise from the co-activation of independent face- and body-selective neural populations.

◆ 99 **Visual experience and the establishment of tactile face-maps in the brain**

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Previous research showed that the parietal brain area called VIP responds to tactile stimuli delivered to the face. These neural responses are spatially organised according to the stimulated part of the face, thus representing a sort of tactile map of the face. We investigated whether the presence of this map is genetically driven, or whether it is environmentally driven. In particular, we investigated the role

played by visual experience. We tested congenitally blind, thus without visual experience, and late blind participants, and found that only late blind individuals, who possess visual experience, showed VIP activation of tactile stimulation of the face. These results suggest that the establishment of tactile face-maps is visually driven, and suggest a role of visual experience on brain development.

◆ **Signs of predictive coding in dynamic facial expression processing**

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Processing social information contained in facial motion is likely to involve neural mechanisms in hierarchically organized brain regions. To investigate processing of facial expressions, we acquired functional magnetic imaging data from 11 participants observing videos of 12 facial expressions. Stimuli were presented upright (clearly perceivable social information) and upside-down (disrupted social information). We assessed the amount of information contained in the brain activation patterns evoked by these expressions with multivariate searchlight analyses. We found reliable above-chance decoding performance for upright stimuli only in the left superior temporal sulcus region (STS) and for inverted stimuli only in the early visual cortex (group effects, corrected for family-wise errors resulting from multiple comparisons across gray matter voxels). Predictive coding proposes that inferences from high-level areas are subtracted from incoming sensory information in lower-level areas through feedback. Accordingly, we propose that upright stimuli activate representations of facial expressions in STS, which induces feedback to early visual areas and reduced processing in those regions. In contrast, we propose that upside-down stimuli fail to activate representations in STS and thus are processed longer in early visual cortex. Predictive coding might prove a useful framework for studying the network of brain regions processing social information.

◆ **Coherence sensitivity of cortical responses to global form**

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Ventral extrastriate areas respond better to coherently organised than to scrambled (zero coherence) global patterns. Here, we used event-related potentials (ERPs) to measure cortical responses to intermediate levels of coherence. The stimuli were arrays of short line segments aligned into concentric or radial global patterns. Coherence was varied by randomising the orientation of a subset of the lines. 128-channel ERPs were recorded while adult subjects viewed a sequence of one-second trials in which the different global patterns and coherence levels were presented in random order. At the end of each trial subjects made a forced-choice judgement about which organisation (radial or concentric) had been presented. The main coherence-sensitive occipital ERP was a bilateral negative response with sources in ventral extrastriate cortex (eg LOC/V4). Its amplitude increased linearly (ie became more negative) with increasing coherence. These results differ sharply from the ERP to motion coherence, which is dominated by a midline posterior response originating in V1/V2, whose amplitude decreases non-linearly with increasing coherence (Corbett 2012, Perception 41, 1515). We conjecture that the motion ERP reflects modulation of V1 activity by feedback from extrastriate areas, and that feedback to V1 plays a much less prominent role in cortical processing of global form.

◆ **Encoding of regularity in the visual cortex**

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The visual system is very efficient in encoding stimulus properties. To explore the underlying encoding strategies in the early stages of visual information processing, we presented participants with L-, T-, and X-junctions in a functional magnetic resonance imaging (fMRI) experiment. For each junction type, we manipulated the amount of configuration regularity (or degrees of constraint), ranging from a generic junction configuration to stimuli resembling an 'L' (i.e., a right angle L-junction), a 'T' (i.e., a right angle midpoint T-junction), or a '+'. We found that the response strength in the shape-selective lateral occipital area was consistently lower for a higher degree of regularity in the stimuli. In the second experiment, using multivoxel pattern analysis we further show that regularity is encoded in terms of the fMRI signal strength but not in the distributed pattern of responses. Finally, we found that the results of these experiments could not be accounted for by two well-known theoretical proposals for constructing stimulus interpretation, namely, the Structural Information Theory and the Minimal Model Theory, at

least not without additional assumptions in those theories. Our results suggest that regularity plays an important role in stimulus encoding in the ventral visual processing stream.

◆ **Representational content in visual ventral stream is modulated by level of specificity**

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People can process objects in a variety of different ways. This study focused on where and by what extent are object representations in the ventral stream modulated by specific task-demands. Using fMRI we ran two one-back tasks: 1) a perceptual identity version where subjects judged if successive objects were identical images, and 2) a category version where successive objects had to be from the same category (e.g. animal). We then used representational similarity analysis (Kriegeskorte et al, 2008, Frontiers in Systems Neuroscience, 2(4)) to investigate how object representations were modulated by the cognitive demands of the two different tasks. Model-based similarity matrices, encoding semantic and perceptual information about the stimuli, were correlated with fMRI similarity matrices. We found that: a) both tasks shared information content within posterior portions of ventral stream and b) lingual gyrii and anteromedial portions of the ventral stream exhibited information content reflecting semantic structure for the category task whereas the same regions exhibited information content encoding visual information (i.e. shape and orientation) for the perceptual identity task. These results suggest that the ventral stream system of object processing is flexible and dynamic, being modulated by the visuo-semantic demands of the task at hand.

◆ **Combined visual and semantic property reconstruction of viewed objects using fMRI**

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How do people process the meaning of objects? Previous reconstruction-based ("mind reading") studies have focused on reconstructing visual information alone. But viewing real objects evokes not only visual processing but also semantic representations. In this study we focused on decoding semantic representations of objects to determine whether they can be reconstructed from fMRI data collected while subjects viewed a series of object images. A semantic feature model was constructed from feature vectors derived from McRae's property norms, while a baseline visual model was acquired by projecting images onto quadrature Gabor wavelet pairs. We conducted leave-one-out cross-validation, where a linear model was fit at every voxel which predicts the voxel activity evoked by the left-out stimulus. In this way activity patterns are predicted from the encoding model. Using Bayesian methods, an a priori set of 148,454 images was used in reconstruction; reconstructions were calculated as the averaged top 100 a priori images having highest posterior probability. To quantify reconstruction quality, we calculated the correlation between visual and semantic features of the original images and their reconstructions. Average visual and semantic correlations of 0.37 and 0.41 respectively suggest that both visual and semantic properties of objects can be reconstructed from brain activation.

◆ **Experience dependent repetition probability effects in the temporal cortex**

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The magnitude of Repetition Suppression (RS) is influenced by the probability of face repetition (Summerfield et al. 2008), implying that perceptual expectations affect repetition related processes in the Fusiform Face Area (FFA). Surprisingly, however, later macaque (Kaliukhovich and Vogels, 2012) and human fMRI (Kovács et al, 2012) studies failed to find such repetition probability (Prep) effects with non-face stimuli (every-day objects and chairs). Thus, it is an unresolved question whether these effects are specific for faces or not. One possibility is that the extensive experience with faces affects the Prep effects. To address this question we used an identical fMRI RS design (n=20) as previous studies, testing the Prep effects for faces and another well trained non-face stimulus category (upright letters of the Roman alphabet). We observed significant RS in the FFA for faces and in the Fusiform Word Form Area for letters. More importantly, this RS was dependent on the Prep of stimuli for both stimulus categories. Our findings, in combination with previous studies, suggest that Prep effects on RS depend on the experience of the subjects with the applied stimulus category.

◆ **Inverse Relationship Between Object and Scene Processing: Consecutive TMS-fMRI**

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Investigations into the neural organization of scene processing have demonstrated that there are several brain regions associated with the representation of a scene, such as regions specialized for object processing (lateral occipital area- LO) and spatial layout (parahippocampal place area- PPA). While behavioural studies have demonstrated that these categories exert an influence on each other, such that scene context can facilitate the identification of objects, or that contextual categorization of scenes can be impaired by the presence of a salient object, little is known about the apparent cortical interactions taking place in order to build the conscious representation of a complete scene. Behavioural research into this question using transcranial magnetic stimulation (TMS) has demonstrated that disrupting object categorization by applying TMS to the left LO can facilitate scene categorization. Here we show that this effect is also reflected in changes to the BOLD signal, such that TMS to the left LO decreased BOLD signal at the site of stimulation while viewing objects and increases BOLD signal in the left PPA when viewing scenes. These findings suggest that these regions, while not on a strict hierarchy, share functional communication perhaps in the form of inhibitory connections.

◆ **Attentional Modulation of the BOLD Signals in Macaque Monkeys performing an Object**

107 **Working Memory Task**

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Although working memory (WM) and attention are often studied as separate cognitive systems, a clear distinction of them is difficult because they functionally overlap. We tested the effect of spatial attention on responses of brain regions recruited by a visual object WM task. Monkeys were trained on two variants of a shape tracking task; one in which a single shape stream was presented either in the lower left or right hemifield, and a second in which two streams were presented simultaneously at both locations. The second task variant required monitoring of the cued stream while ignoring the uncued stream. Functional whole brain MRI data were acquired with a 3T Siemens Allegra scanner. Statistical maps identified a network of brain regions involved in the WM task that was comparable for both paradigms. An analysis of trial-averaged BOLD signals revealed stronger responses for visual areas contra-lateral to the attended shape. Attentional modulation increased for down-stream visual areas and was strongest in TEO. Ventral lPFC showed response increases in the second paradigm irrespective of attended location, suggesting that this area is more involved in orienting attention rather than in WM. The data confirms a general spatial and functional overlap of WM and attention.

◆ **Parametric fMRI activation of cortical regions during visual speed discrimination in**

108 **healthy and diabetic patients**

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Here we studied the BOLD functional magnetic resonance imaging (fMRI) responses of 49 healthy subjects during a speed discrimination visual task. The participants detected the faster of two dots, one in each visual hemi-field (moving with 4 possible speed differences). Speed discrimination recruited parietal and occipital regions in relation to stimulus physical characteristics and hMT and frontal regions modulated with task difficulty. BOLD responses were parametrically modulated such that conditions with higher speed differences showed higher activation in sensory regions and lower activation regions related to perceptual decision (beta values per condition tested with ANOVA, $p<0.05$). Furthermore, a contrast comparing the response to speed differences in the same visual hemi-field revealed statistically significant activation in the contra-lateral insula, suggesting its important role in interhemispheric integration of motion information. We also studied 36 patients with type 2 diabetes in whom we observed some of the same regions identified in the healthy brain. Whereas in the latter a linear parametric effect of speed discrimination was consistently found, this was not identified in type 2 diabetic patients, suggesting that these might have a different hemodynamic response function.

◆ **Investigating hippocampal activation elicited by watching indistinct motion stimuli**

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Almost for a decade now there is an inconclusive debate about the role of hippocampus in visuo-spatial perception. So far, related studies have focused on static images as visual input. In real life, however, we are confronted mostly with dynamic visual scenes, which may or may not be novel. In previous fMRI experiments, we compared brain activation elicited by meaningful visual motion stimuli depicting movement through a virtual tunnel and indistinct, meaningless visual motion stimuli, achieved through spatio-temporal phase scrambling of the same stimuli [Fraedrich et al, 2012, J Cogn Neurosci, 24(6), 1344-57]. The indistinct visual motion stimuli evoked bilateral hippocampal activation, whereas the corresponding meaningful stimuli did not. In the present follow-up study, we investigate whether temporal changes in image content are responsible for continuous hippocampal activation by manipulating the temporal characteristics of our indistinct visual motion stimuli. Since static phase-scrambled images have not been reported to activate the hippocampus, we expect a graded increase of hippocampal activation with increasing high-frequency content in the temporal dynamics of the visual stimuli. This would support our hypothesis that the observed hippocampal BOLD response is caused by memory retrieval related to the indistinct scenes.

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◆ **Bilateral stimulation strengthens contralateral bias in extrastriate visual cortex**

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Visual scenes are initially processed via segregated neural pathways dedicated to either of the two visual hemifields. In contrast, higher-order brain areas comprising the ventral visual stream are thought to utilize invariant object representations, abstracted away from low-level features such as stimulus position. Here, we assessed the nature of such higher-order object representations using fMRI-based multi-voxel pattern analyses, showing that their degree of position invariance is dependent on the encountered stimulus configuration. Under unilateral visual stimulation, fMRI activation in both the ipsilateral and contralateral hemisphere allowed nearly perfect classification of the presented object category (i.e, position invariant coding). However, adding a stimulus in the opposite hemifield elicited a very pronounced contralateral bias in activity patterns, re-establishing the segregation known to exist in earlier processing stages (i.e., position dependence). The contralateral emphasis under bilateral stimulation conditions likely reflects the brain's common modus operandi given that natural visual scenes generally contain various objects simultaneously. The current findings extend previous work by showing that configuration-dependent modulations in representational invariance as previously observed in single neuron responses have a counterpart in human neural population coding. Moreover, they corroborate the emerging view that certain functional characteristics ascribed to ventral visual stream processing require reconsideration.

◆ **Subjective artificiality directs visual processing during photo perception to ventral, subjective authenticity to dorsal streams**

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A snapshot often captures a moment of real life in a naturalistic fashion, while many professional photographs create an artificial image that presents an arranged and modified reality. We wanted to address the question whether subjective judgment of a motif as artificial compared to judging it as naturalistic changes the way in which it is processed in the brain. During fMRI, photographs of real sceneries and artistic pictures matched for semantic content were presented for 80ms each. Participants were asked to assess all of these for degree of artificiality to study the parametric modulation of visual perception weighted by the subjective artificiality rating. Watching pictures, rated as being artificial, involved more strongly the bilateral anterior pole, precuneus, posterior cingulate cortex and posterior hippocampus, which suggests involvement of autobiographical memory networks (Pichon and Kell, 2013, JNeurosci, 33(4):1640-50). When pictures were rated as naturalistic a large bilateral action-related network was activated including the intraparietal sulcus, premotor cortices, the inferior frontal gyrus,

and insula. Pictures judged as natural were retrospectively also labeled as more dynamic. Our data suggest that perception of naturalistic scenes engages action-related networks to a greater extent than artificial scenes possibly due to implicitly higher dynamics in the static images.

◆ 112 **What is the relationship between Cingulate Sulcus Visual Area (CSv) and Cingulate Motor Area (CMA)?**

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Previous studies of the posterior cingulate sulcus have indicated a bilateral visually responsive region, named CSv, specialised for optic flow processing [Wall and Smith, 2008, Current Biology, 18, 1-4]. However, in other studies this area has also been associated with motor control and is referred to as CMA [Picard and Strick, 1996, Cerebral Cortex, 6, 342-353; Amiez and Petrides, 2012, Cerebral Cortex]. Given the spatial resolution of fMRI group results, it is not possible to be sure whether the previous reports of a visual region and a motor region in the posterior cingulate are two adjacent but separate regions, or a single 'visuo-motor' region. Results of our fMRI studies combining visual optic flow with motor responses tracking the direction of self-motion initially appeared to support the possibility of a single 'visuo-motor' region. Specifically, the visually driven activation in the posterior cingulate appeared to switch hemispheres depending on the hand used to control the joystick. However, further investigations using separate motor and visual localisers in the same participants, as well as the combined visuo-motor task, lead us to conclude that posterior cingulate contains separate motor and visual regions.

◆ 113 **Prefrontal hemodynamic activation while watching movies**

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Self-referential properties, such as attention, interests, preference, influence the observer's perception of visual scene. Such properties are related to the functions of prefrontal cortex [Jenkins et al, 2008, PNAS, 105(11), 4507-4512]. We measured hemodynamic changes around prefrontal cortex while observers watched movies, and examined the relationship between the subjective evaluation of the movies and prefrontal activation. Method: Stimuli consisted of twenty silent movies, such as dogs playing, a scene of driving a car, a popular cartoon movie, etc. After a 20 sec resting-time, observers watched a movie for 15 sec followed by another 20 sec resting-time. Then they responded to four questions about the movie on a five-point scale; 1.whether s/he was interested in the movie, 2.wanted to see the movie more, 3.liked it or not, 4.was familiar with the scene. Oxy-hemoglobin change around prefrontal cortex was monitored before to after the stimulus presentation by a 22ch Near-Infrared-Spectroscopy (Hitachi, ETG-4000). Twenty-one volunteers participated in the experiment. Results: The oxy-hemoglobin change generally started to increase before stimulus presentation, presumably reflecting expectations, and to decrease during watching stimulus movies. The magnitude of oxy-hemoglobin change showed inverse correlations with observers' interests and preferences to the movies, but not with familiarity.

◆ 114 **Repetition-induced decreases in BOLD fMRI signal for recognition of 'communicative' (intransitive) and tool use (transitive) gestures**

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Neuroimaging activation studies of intransitive and transitive gesture recognition converge on the idea of largely overlapping neural substrates (e.g. Villarreal et al 2008, pointing merely to greater engagement of the left inferior frontal gyrus for intransitive actions). Here, repetition-induced changes in BOLD-fMRI signal were studied to look for differential processing of the two gesture categories. Event-related data were acquired from twelve right-handed adults during four experimental runs. Two back-to-back videos depicting for 2.5 s either the same or different actions (12 from each category) were separated by a 1.5s delay interval (and after short variable ISIs followed by imitation of the second movie). On repetition trials, the gestures were always shown from different perspectives to avoid signal adaptation due to watching identical low-level perceptual attributes. Repeated observation of intransitive gestures resulted in significant signal decreases, bilaterally at the border of the caudal middle temporal and occipital cortices, and in ventro-medial prefrontal cortices. Much weaker activity suppression was observed for repeated transitive gestures. Direct between-category contrasts of the adaptation trials revealed significantly greater decrease in the posterior cingulate gyrus for intransitive gestures. These effects are consistent with the idea of different patterns of signal modulation within a common network.

◆ **Classification of Material Properties in fMRI**

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The taxonomy of material categories has previously been investigated with fMRI [Hiramatsu et al, 2011, Neuroimage, 57(2), 482-494]. Here we wanted to explore whether information about material properties can be found in the BOLD response to 84 images showing a large variety of different materials. We asked subjects to rate these images with respect to colorfulness, roughness, texture, hardness, orderliness, & glossiness. We scanned 7 subjects with fMRI while they viewed the images. A linear classifier was applied to visually responsive voxels to discriminate between images with high and low ratings. We found classification accuracy on the fMRI data to be significantly better than chance only for colorfulness (63%, $p<0.001$), roughness (60%, $p<0.05$), and texture (64%, $p<0.001$). Since gloss has received a lot of attention lately, we wanted to look more closely into the representation of glossy materials. We scanned another 6 subjects viewing 58 images of materials selected from a large database of 1492 images as being perceived as very glossy or very matte. A classifier could discriminate the brain activation caused by matte and glossy images with an accuracy of 59% ($p<0.01$). Our results demonstrate that information about the properties of materials is present in fMRI activation patterns.

◆ **Multidimensional EEG analysis reveals a transient cortical network in early visual processing**

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Functional integration and segregation in visual perception have been mainly studied in severe neurobehavioral deficits, suggesting that brain activation is stimulus-dependent. Primary sensory areas have shown to be hyperactivated when presenting sinusoidal gratings. Conversely, functional integration among such areas is reduced in the presence of complex stimuli. However, the relation between these two cortical properties has been largely overlooked. We aim to investigate whether it is possible to measure functional integration along segregation in early visual areas and the underneath temporal dynamics. Ten participants were presented with sinusoidal gratings at two different spatial frequencies (2.8 and 6 cpd) to elicit steady-state visual evoked potentials (SSVEPs). Wavelet analysis was applied to the SSVEP responses to elucidate the temporal properties of brain rhythms. Our stimuli elicited a frequency-specific local network in parieto-occipital area that arises at stimulus onset and whose intensity diminishes in the steady response. This network is highly dynamic as synchronizes differently in each spectral band. Our results might imply an integration of top-down signals coming down from different areas that contribute to the segregation reported in visual areas. This study provides evidence that the interplay between functional integration and segregation performs an important role in visual perception.

◆ **Dynamics of directed information transfer in visual processes**

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Visual stimuli quickly evoke processing in a network of primary visual and higher-level brain areas, giving rise to dynamic interactions between them that are poorly understood. Here we investigated directed interactions in visual processing via time-varying Granger-causal modeling. Using fMRI we localized in each subject six regions of interest (ROI) in each hemisphere: primary visual cortex, lateral occipital complex, fusiform gyrus, area MT+, lateral intraparietal sulcus and the frontal eye field. In a separate EEG session subjects performed a target detection task on the center of the screen while we briefly presented checkerboards in the lower left and right visual field. From the EEG we estimated time-series of activity in each ROI using a distributed linear inverse solution (WMN) and realistic individual head-models. With adaptive MVAR modeling we then derived the directed influence between all ROIs in time, scaled by the instantaneous spectral power (wPDC). The results show peak driving from primary visual cortex at expected latencies and strong early influences from parietal areas onto primary visual cortex. The work demonstrates the potential for studying dynamic relationships between bottom-up and top-down visual processes by combining EEG source imaging and wPDC.

◆ **Second-order visual mechanisms and interhemispheric asymmetry**

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It is a common view that the right hemisphere realizes global description of visual scenes. The first step of visual processing is local linear filtering which is bilaterally performed in a striate cortex. After that second-order visual mechanisms (SOVMs) spatially integrate the first-order filter outputs. The aim of our study is to reveal whether hemispheric asymmetry of visual processing arises at this level. To solve this problem we used mismatches between VEPs to nonmodulated and orientationally modulated checkerboard texture, composed of Gabor micropatterns. VEPs were recorded by 20 leads. 48 observers participated in the experiments. It was found that the mismatch has 3 waves. But in our opinion only the first wave which is generated between 170 to 250 ms represents SOVMs activity. Subsequent waves forming after 300 ms are apparently related with decision-making and preparation of behavioral response. We calculated localization of dipole source of this mismatch wave using one-dipole model. The dipole was located in the area 18 of the right hemisphere. Obtained results suggest that the right-side asymmetry during visual processing is formed as early as the initial stage of the spatial pooling of local orientation information.

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◆ **Is the polarity of multifocal VEPs related to visual-cortex folding?**

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The idiosyncratic folding of retinotopic visual cortex is believed to dictate the dependence of multifocal visual evoked potential (mfVEP) amplitude and polarity on stimulus location in the visual field. We assessed that relationship in four subjects by comparing mfVEPs with measures of corresponding fMRI-derived regions of interest (ROIs) in V1 and V2, i.e., their curvature, orientation and distance from electrode. Dartboard-shaped, polarity-sensitive mfVEP activity maps were obtained as Pearson's correlations of the local signals with the polarity-corrected mean for the whole field. Wedge and ring stimuli for fMRI-based retinotopic mapping matched the size and texture of mfVEP stimuli. ROI surface orientation, location, and curvature were determined by Matlab scripts processing BrainVoyager vertex data. Heuristic checks verified the validity of these measures. MfVEP polarity reversals seemed related to the extent of surface curvature. MfVEP activity was correlated with ROI orientation and distance-from-electrode for V1, with up to 25% explained variance. Activity was further correlated with ROI distance in V2 but not with the ROI's orientation. Polarity reversals between upper and lower hemifield might reflect surface orientation in V2. In summary, mfVEP polarity reversals depend on V1 and V2 folding but further unknown factors also contribute.

◆ **Does resting state functional connectivity reflect visual system architecture?**

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Spontaneous fMRI activity is spatiotemporally organized into functional networks; sets of brain regions that are co-activated during certain tasks and correlated during rest. The visual system exhibits a hierarchical and retinotopic organization. Does resting-state fMRI activity reflect this visual system architecture? We retinotopically mapped the visual system of 44 participants, and explored their resting-state activity in the context of known anatomical and functional connections. We specifically examined the correlations between areas along the visual hierarchy (LGN, V1, V2, V3, V4, and MT), and the correlations between different retinotopic subregions, i.e. regions encoding the foveal versus the peripheral part of the visual field. A strong factor influencing the strength of all correlations was distance. Interhemispheric correlations between homotopic areas were especially strong and exceeded correlations between LGN and cortex. In contrast, intrahemispheric correlations along the visual hierarchy were moderate, and within-area correlations between periphery- and fovea-encoding regions were particularly weak. Correlations in the dorsal processing stream seemed slightly stronger than correlations in the ventral processing stream. These correlation patterns were robust and only marginally altered under task

conditions. Together, they imply that resting-state fMRI activity in the visual system follows both its hierarchical and retinotopic organization.

◆ **Individual differences in metacontrast masking are reflected by activation of distinct**
121 **fronto-parietal networks**

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In metacontrast masking the visibility of a briefly presented target stimulus is reduced by a subsequent masking stimulus whose contours fit snugly around the contours of the target. In several recent studies we have shown that observers differ qualitatively in the time course of masked target discrimination. Whereas one type of participants shows increasing discrimination performance with increasing stimulus onset asynchrony (SOA) between target and mask (Type-A observers), another type of participants exhibit decreasing discrimination performance with increasing SOA (Type-B observers). These differences in discrimination performance are complemented by differences in subjective phenomenology and the use of different perceptual cues. Here we present a neuroimaging study in which we aimed to localize those brain areas that reflect the time courses of behavioral masking functions. To this end we tested for brain activations that closely follow the behavioral masking functions of either Type-A or Type-B observers. Results show that activation in bilateral putamen correlates with behavioral masking functions regardless of observer type. Frontal and parietal brain regions including the insula, the inferior frontal gyrus and the precuneus show type-specific correlations. Overall, findings suggest that individual differences in metacontrast masking reflect differences in attentional mechanisms and higher-level vision processes.

◆ **Neural correlates of structural and holistic object representations in dependence of**
122 **attention**

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A fundamental question in visual cognition is whether objects are stored as structural (part-based) descriptions or as holistic views. Hybrid models integrate both formats of representation and predict a critical role for attention. Visual attention enables structural descriptions by segmenting and binding object components. However, also in the absence of attention recognition may still proceed by matching objects to view-based representations. In this fMRI study we probed object-responsive brain areas for characteristics that are compatible with either holistic or structural object representations. We devised a novel paradigm in which participants viewed images of intact and slightly scrambled (split) objects under conditions of spatial attention or inattention. Univariate fMRI analysis showed increased engagement of lateral occipital cortex for attended (but not unattended) split objects relative to intact objects – compatible with a structural description account. Irrespective of attention we found elevated activation for intact relative to split objects – compatible with holistic representations – in the hippocampus and the superior frontal gyrus. FMRI decoding analysis further corroborated the presence of both structural and holistic representations as predicted by a hybrid model of object recognition. Our results reveal the representational format of object representation in the human brain and elucidate the dependence on attentional demands.

◆ **The quantum nature of attention: a time-resolved fMRI study**
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When directed to multiple spatial locations, attention has traditionally been thought to be simultaneously distributed among them (Eriksen & St James, 1986, Perception & Psychophysics 40 (4): 225–240). Rhythmic presentation of spatially disjoint targets at optimal frequencies improves their detection, however, suggesting that covert attention may in fact be rapidly cycled between attended locations (Landau & Fries, 2012, Current Biology, May; Van Rullen et al., 2007, PNAS, 104 (49), 19204-19209). We used time-resolved fMRI (TR = 88 ms) to investigate whether attending to multiple visual items results in serial rather than simultaneous enhancement of their representations in visual cortex. We measured extrastriate signal evoked by stimuli in the four quadrants under three conditions. A simultaneous, 400 ms, 25% increase in luminance of all four items served as a model for simultaneously

distributed attention. A sequential, 100 ms, 100% increase in luminance for each item served as a model for sequentially allocated attention. We compared these with an attended condition, in which participants monitored the four items (whose luminance did not change). The phase of evoked BOLD response changed predictably across the visual field under sequential and attended conditions ($p < .05$), but was constant under simultaneous conditions.

POSTERS : BRIGHTNESS, LIGHTNESS AND CONTRAST

◆ **The motion of the occluding surface enhances perceptual transparency**

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When a stripe is partially overlapping a figure of different colour, it is possible to see the stripe as apparently transparent (i.e. the Rosenbach effect). This effect, which has also been dubbed phantom effect [e.g. Tynan and Sekuler, 1975, Science, 188, 951-952], is stronger when the occluded surface is moving. An experiment is presented, aimed at testing the role of motion of the occluding surface on the perception of transparency in the Rosenbach effect. Participants (n=12) were asked to judge, on a seven points Likert scale, the perceptual transparency of the occluding surface, which could be (a) static, (b) moving at a slow velocity (i.e. 3.7 cm/s) or (c) moving at a high velocity (i.e. 12.4 cm/s). Physical transparency, lightness-contrast and –polarity were also manipulated. Results show that the perception of transparency is enhanced when the occluding surface is moving: scores for perceptual transparency are higher for animations than for static images, and for slow animations as compared with fast animations ($p<0.05$). A significant interaction between Contrast and Transparency ($p<0.0001$) indicates that a low contrast facilitates the perception of transparency in physically opaque surfaces. A possible explanation is suggested, based on the role of both motion and simultaneous lightness contrast.

◆ **Randomized checkerboard contrast illusion: theoretical implications on Gestalt principles**

125 **in brightness perception**

M Hudak[1], J Geier[2] ([1]Dept. Gen. Psych, Pazmany Peter Catholic University, Hungary; [2]Stereo Vision Ltd, Hungary; e-mail: hudakmariann@gmail.com)

The checkerboard contrast illusion comprises two identical grey squares, one substituting a white square, while the other a black square of a black-white checkerboard. The grey square surrounded by four white squares seems brighter than the one surrounded by black squares, contrary to the simultaneous contrast illusion [De Valois & De Valois, 1988, Spatial Vision. New York, Oxford University Press]. The anchoring theory attributes this phenomenon to the belongingness of the grey squares to the diagonal set of uniform black or white squares, within which the highest luminance rule is applied to explain the illusion [Gilchrist et al, 1999, An anchoring theory of lightness perception, Psychological Review, 106(4), 795-834]. We eliminated the diagonal sets by randomizing the location of the black and white squares. However, the illusion persists. Therefore, the illusion cannot be explained by grouping the grey squares to the diagonal sets of uniform squares. Since grouping and regularity of the pattern are not necessary conditions for the illusion, another explanation should be sought. We suggest a filling-in type of explanation, whose computer simulation will be presented to show that the checkerboard contrast illusion can be explained at a low level.

◆ **Varying luminance of distracters in alignment task**

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The magnitude of misalignment was measured in psychophysical experiments with the horizontal three-spot stimulus (the interval distance, 30 min-of-arc) and three distracter-spots situated one at a time below the medial and above both lateral stimulus terminators at the distances: 0.75, 1.5, 2.25, 3, or 3.75 min-of-arc. The terminator and background luminance was fixed at 75 and 15 cd/m2, respectively, and the distracter luminance varied from 3 to 31 cd/m2. The subjects adjusted the middle stimulus spot (together with the flanking spot) into a position which made all three terminators to be aligned perceptually. The error magnitude varied in dependence on the terminator-distracter distance and luminance difference, like in the previous experiments [Bielevicius et al, 2007, Perception, 36 ECVP Supplement, 38]. However, the maximum values of two misalignment types were found at different terminator-distracter distances: those of the attraction effect produced by the bright distracters were observed within the 1.5-3 min-of-arc distance range, and the maxima of the repulsion induced by the dark distracters were registered at the 0.75-1.5 min-of-arc distances. The results might be interpreted in terms of functional properties

of the retinal ON and OFF receptive fields [E.J.Chichilnicky and R.S.Kalmar, 2002, The Journal of Neuroscience, 22(7)].

◆ **Highlight shape influences gloss perception**

127 J J Assen, S C Pont, M W Wijntjes (Perceptual Intelligence Lab, Delft University of Technology, Netherlands; e-mail: janjaap.vanassen@gmail.com)

Gloss perception highly depends on the 3D shape and the illumination of an object. In this paper we investigated the influence of a specific property of the illumination namely the form of the highlight. A light box in combination with differently shaped masks was used to illuminate spherical stimuli that were painted with various degrees of gloss. This resulted in a stimulus set of 6 different highlights and 6 different gloss levels, a total of 36 stimuli. We performed three different experiments of which two took place with photographs on a computer monitor and one with real scenes in the light box. The observers had to perform a comparison task choosing which of two stimuli was more glossy and a rating task in which a single stimulus was given a score for glossiness. The results show that, perhaps surprisingly, more complex highlight shapes were perceived to be less glossy than simple shapes such as a circle or square. These results suggest that highlight shape complexity is not the main criterium for the "naturalness" of illumination.

◆ **Effects of Background Reflectance and Illumination Level on the Estimated Freshness of Vegetables**

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Luminance distribution information is a critical cue for estimating visual freshness of vegetables, such as strawberries [Arce-Lopera et al, 2012, i-Perception, 3(5), 338–355] and cabbages [Arce-Lopera et al, 2013, Food Quality and Preference, 27(2), 202–207]. However, it remains unclear how robust is the freshness estimation against environmental variation, such as variations of lighting and background conditions. Therefore, we conducted an experiment to investigate the effect of several environmental parameters on our visual estimation of fresh vegetables by controlling the image information. First, we took calibrated pictures of fresh vegetables: cabbage, carrot and komatsuna (Japanese Mustard Spinach) that gradually degraded in a controlled environment. Next, to investigate the effect of the luminance contrast on freshness estimation, we created stimuli with several levels of luminance contrast between the vegetable surface and the background by controlling their luminance level. As a result, we found that the background reflectance do not affect visual freshness estimation. On the other hand, visual freshness estimation depends on the absolute luminance levels of the vegetable surface but it saturates over a certain illuminance. Those results suggest that visual freshness estimation is quite robust against environmental variation except when the illuminance level is low.

◆ **Relation between lightness perception and luminance statistics of natural scenes**

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Results of some studies have shown that the perceived lightness of a stimulus depends on the context of the surroundings in natural scenes. However, few studies strictly divide the effects of context and those of luminance statistics in natural scenes. This study investigated the perceived lightness of a patch presented on a random-dot pattern having no context while manipulating the variance of the pattern luminance. We measured the illuminance and the luminance distribution of actual scenes to examine whether the illumination in our environment is related to some statistics of the luminance distribution of the scenes. Observers matched the perceived lightness of a test patch presented on the random-dot stimulus to that of a comparison patch presented on a uniform gray background by adjusting the comparison patch luminance. Results showed a correlation between the matched luminance and the variance of luminance distribution of the stimulus pattern. Field measurements revealed strong correlation between the variance of the luminance distribution in natural scenes and the illuminance measured in the scene. These results suggest that the visual system might refer some statistics of luminance distribution in an actual environment to estimate the illumination of the scene to produce lightness perception.

◆ **The psychophysical contrast response of the human visual system to freely-viewed naturalistic movies**

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In real-world vision, both objects in the environment and the observer's eyes move, but these conditions are rarely replicated in psychophysical experiments. In our study, observers watched a continuous movie of naturalistic stimuli (a nature documentary) making free eye movements. Localised regions of the image were incremented in contrast within a 1 octave spatial band, and the position of these targets on screen was updated at 120 Hz to remain at the same retinal location as the observers eyes moved. Observers reported the location of the contrast increment, relative to their fovea (4AFC). We fitted a contrast response function based on these judgments using simulations (MCMC) to estimate the full Bayesian posterior of a multilevel model incorporating inter-subject variability. There was no evidence of saturation within the range of contrasts occurring in our stimuli, and the fastest response acceleration appeared for target bands around 1.5 cycles per degree, indicating that the contrast sensitivity function peaked at lower spatial frequencies than for static narrowband stimuli. We also isolate predictive stimulus features using statistical learning techniques. Experiments with simple grating stimuli may measure aspects of the human visual system that are atypical of vision in the real world.

◆ **Subjective image quality evaluation method for digital images that reflects users' characteristics**

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In the field of marketing, with diversification of individual values, the need to classify products according to users' preferences has been increasing. Needless to say, there are differences among individual preferences in the evaluation of image quality. This study focuses on differences among evaluations of camera users and examines the image quality evaluation method, which considers user characteristics. In particular, an experiment to evaluate the subjective image quality using scenes of "Landscape," "Portrait," and "Still Life" was conducted. In addition, participants were required to answer a questionnaire about their preferences that relate to photos and their profiles. Cluster analysis and the chi-square test were applied to the results of conjoint analysis and the questionnaire. As a result, the participants were classified into two groups: a group of camera users who are particular about photos, and another group of camera users who are not particular about photos. The results also showed differences between the groups of camera users in their perception of psychological factors such as brightness, saturation, and contrast. Especially significant differences were found in perceptions of still-life scene with varying contrast and saturation.

◆ **Visual performance in the mesopic range of outdoor lighting**

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The search for cost-efficient outdoor lighting has brought light-emitting diode (LED) lamps as a replacement for older type high-pressure sodium lamps (HPS). Various LED lamps have been introduced in the market and there is little data about visual performance in the mesopic range under those LED illuminations. The aim of this research was to evaluate visual performance in the mesopic range under two illumination conditions: HPS lamp and LED lamp optimized for minimal disruption of circadian rhythm [Zukauskas et al, 2012, Applied Optics, 51(35), 8423-8432]. During the experiment the subject was fully adapted to LED or HPS illuminance. Four luminance levels 0.1, 0.3, 1 and 3 cd/m2 were used. Visual performance was evaluated by reaction time (RT) to low contrast stimulus displayed at 18 deg eccentricity from the fixation point and colour discrimination with the Farnsworth-Munsell Test (FMT). Results showed that RTs and FMT scores for colour discrimination were better under all luminance levels of LED lamp in comparison to HPS. For both illuminants RT degradation had logarithmic dependency from increasing luminance, while colour discrimination was reducing linearly with diminishing luminance.

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◆ **Observers rely more on shadows than on shading and highlights when comparing illumination conditions**

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When comparing illumination conditions, human observers mostly extract the direction of the light source from low-level image cues. The question we ask here is whether they are able to distinguish other low-level aspects like diffuseness and number of light sources, and what kind of stimulus information is most important for this task. We use a teapot, an orange and a tennis ball from the ALOI database (Geusebroek et al., IJCV 2005) to create stimuli either with a single light source direction that varies in diffuseness or with two light source directions that vary in separation. Observers are presented with all three objects on every trial, and have to indicate which one is illuminated differently from the other two. We measured behavioural data as well as eye-movements to determine where our participants were looking. Results show that participants performed above chance for most combinations. Interestingly, eye-movement data show that participants primarily look at the shadows (60% of the fixations), in favour of shading (30%) and highlights (10%). This is in line with a model we presented at ECVP 2008 that shows that variance in performance for this task could best be modelled by using shadow information.

◆ **Interpolation of illuminant cues across scenes with light fields induced by a mixture of a proximal and a collimated light source**

134

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We examined how the visual system combines information from distant parts of the scene to estimate and discount the local light field. We rendered scenes with two bumpy rectangular grey surfaces separated by a gap. The scene was lit by a yellow proximal source (simulated distance: 1.15m) and a blue collimated source placed to the left and right of the observer respectively. The light impinging on a surface patch depended on the orientation of the patch to both sources and its location with respect to the yellow source. On each trial, a briefly flashed test surface patch (750ms) appeared at any of three locations within the gap, oriented at any of seven azimuths. Participants made forced-choice judgments of the yellow-blue balance of the test patch as we varied its yellow-blue chromaticity (staircase). We estimated their indifference points for each of the location-orientation conditions and compared human performance to that of an ideal observer discounting the light field. Five of seven participants correctly discounted the effect of changes in surface orientation. All participants failed to account for the effect of the proximal source as the target changed position suggesting that the visual system does not correctly discount for proximal illuminants.

◆ **Brightness filling-in incorporates information about 3-D structure**

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A range of illusions demonstrate that edge luminance contrast strongly influences the perceived brightness of an enclosed homogenous region. Such phenomena are compatible with a filling-in process that spreads contrast information from borders to the interior. This process is disrupted by backward masking, where the apparent brightness of a target is reduced by the brief presentation of a mask (Paradiso & Nakayama, 1991, Vision Research, 31, 1221-1236). Here we ask whether filling-in processes occur at early or intermediate stages of visual processing, using disparity-defined slanted surfaces. In two experiments, we manipulated the three-dimensional (3D) properties (slant direction) of the target and mask, and measured the differential disruption that masking causes on brightness judgments. On a given trial, participants (N=7) judged which of two successively presented target surfaces had a brighter centre, with a staircase used to control stimulus luminance. We found that masking was greatest when the target and mask had the same 3D orientation, with opposing slants attenuating the interference in apparent brightness. Control measures ruled out explanations based on monocular image properties. These results suggest that brightness filling-in operates at an intermediate stage of visual processing that involves information about the 3D properties of the scene.

◆ **Lighting direction and visual field modulate the brightness of 3D objects**

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When interpreting object shape the visual system assumes that illumination comes from above left. Does the direction of lighting influence object brightness (and/or perceived intensity of illumination)? An array of nine cubes was stereoscopically rendered. Individual cubes varied in their 3D pose, but all possessed identical triplets of visible faces. The cubes were illuminated from one of four directions: above-left, above-right, below-left, and below-right (±24.4o; ±90o). Simulated illumination intensity possessed 15 linear levels. "Standard" cubes were illuminated from above-left at intensity 8; comparison cubes were illuminated from the four directions and appeared in either the left or right visual field. Using the method of adjustment we determined comparison cube illumination required to establish subjective equality with the standard cubes as a function of comparison cube visual field, illumination elevation, and illumination azimuth. Cubes appeared significantly brighter in the left visual field (p=.008), and when illuminated from below (p<.001). The enhanced brightness of cubes lit from below was greatest when also lit from the right (p=.001). Cubes lit from below appear brighter (more highly illuminated) than identical cubes lit from above, due perhaps to long-term adaptation to downward lighting. Brightness is amplified in the left visual field, presumably via attentional enhancement.

◆ **The Effect of Gloss on Perceived Roughness**

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Previous study has shown that magnitude roll-off factor (ß) and RMS height (σ) that related to $1/f^{\beta}$ random phase noise surface topology significantly affect perceived roughness under the assumption of Lambertian reflectance [Padilla, Stefano, et al. 2008, Vision Research, 48.17 : 1791-1797]. We further employed a glossy reflection model to investigate if surface gloss affects perceived roughness of such surfaces. We conducted a paired comparison experiment and scaled perceived roughness (relative difference) using Maximum Likelihood Estimation. We found consistent results with literature in that perceived roughness increases with the decreasing of ß and the increasing of σ (F=93.964 and 144.981, both with p<0.01). Interestingly, surface gloss significantly affects roughness perception (F=127.847, p<0.01). In the surface pair of the same ß and σ, the glossier one was perceived less rough. This difference gets smaller as the surfaces become rougher (decreasing ß or increasing σ). It can be seen from the insignificance within the pair of smallest ß and largest σ (t=1.215, p=0.248), which is roughest according to literature. We concluded that surface gloss affects perceived roughness, but the degree of influence depends on the surface topology. [NSFC Project No. 61271405]

◆ **Dimensionality of the Perceptual Space of Achromatic Surface Colors**

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The perceptual space of achromatic colors is often viewed as being one-dimensional, ranging from white to black over all shades of gray. In a series of experiments we tried to systematically investigate the dimensionality of achromatic color space. Experiments were conducted in an illuminated room insuring that all stimuli were perceived as surface colors. Results show that context free stimuli (simple gray patches) can be represented with a single perceptual dimension. Introducing surrounds in a second experiment shows that we need a second perceptual dimension to represent the color of the infield with these more complex stimuli. The shape of the psychometric functions in this second experiment is closely related to the perceptual dimensionality for these stimuli. In a third experiment, we wanted to investigate the form of these two-dimensional psychometric functions for same-different judgments conducted on infield-surround configurations for individual observers. The form of these psychometric functions shows that one perceptual dimension is not enough to explain what we perceive when looking at infield-surround stimuli.

◆ **What happens to the Staircase Gelb effect when the highest luminance is not white?**

139 O Daneyko, D Zavagno (Department of Psychology, University of Milano-Bicocca, Italy; e-mail: olga.daneyko@gmail.com)

In the staircase Gelb effect, five squares cut from achromatic Munsell (aM) papers 2.0, 4.0, 6.0, 8.0, and 9.5 are arranged in a row from the darkest to the lightest and illuminated by a spotlight, often referred to

as “Gelb illumination”. The perceptual outcome is a compressed lightness range, from middle grey to white, or super-white. The illusion has been extensively used as a case study for the Anchoring Theory (Gilchrist et al, 1999, Psychological Review, 106, 786-834). According to such theory, the highest luminance (hL) of the configuration is assigned the value of white in the local framework. We studied the role played by such hL in the compression rate of the illusion, by manipulating the hL target – four levels: 9.5, 9.25, 9.0, and pastel yellow (Munsell 5Y 9/4 with luminance between the values for 9.25 and 9.0). Results show that the achromatic hLs are off the aM scale, appearing either luminous or super-white; the brightness of the yellow hL target appears also greater than 9.5. The compression effect drops as the hL is lowered. This “decompression” is statistically significant only for targets 2.0 and 4.0 with hL 9.0 and yellow.

◆ **Effect of stimulus intensity on LRP latency, RT in simple and choice tasks**

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Van der Molen and Keuss [1979, Quarterly Journal of Experimental Psychology, 31, 95-102; 1981, Quarterly Journal of Experimental Psychology, 33, 177-184] reported U-shaped relationship between reaction time (RT) and loudness in difficult tasks requiring choice responses. This effect was replicated by Jaskowski and Wlodarczyk [2006, International Journal of Psychophysiology, 61, 98-112] for ultrabright and large visual stimuli. In the current study, we used ERP to investigate the locus of this paradoxical elongation of RTs for extremely bright and large stimuli. The luminance of stimuli was manipulated. Same we also tested a different group of participants with two disparate auditory tons and a five different loudness conditions, task simple and choice reaction. The RT-luminance relationship was monotonic for simple responses and U-shaped for choice responses. Notably, LRP-R was independent of stimulus intensity for both tasks. S-LRP latency changed with brightness similarly to RTs. These results support Van der Molen and Keuss' proposal that it is the response selection stage that is affected by very strong stimuli. Our study clearly indicates that response selection is influenced by intensity changes irrespective of whether visual or auditory stimuli are used, resulting in a U-shaped relationship between RT and intensity when the task is difficult.

◆ **Dark vs light stimuli in psychophysical tasks: a search for possible moderators of the**

141 **contrast polarity effect**

M Gerdes, C Meinecke (Institute of Psychology, University of Erlangen-Nuremberg, Germany; e-mail: marlis.gerdes@psy.phil.uni-erlangen.de)

The goal of studying contrast polarity is to determine if information for display users should be presented in dark print on a lighter background or vice versa. The existence of a contrast polarity effect, i.e. the superiority of dark stimuli compared to light ones, is controversial in the literature [e.g. Chan and Lee, 2005, Behaviour & Information Technology, 24(2), 81-91; Buchner et al, 2009, Ergonomics, 52(7), 882-886], yet the reasons for why the effect is so unstable have not been looked into. We conducted a series of psychophysical experiments involving basic, non-semantic stimuli like lines or arrows, in order to keep top-down influences at a minimum. Absolute contrast of dark vs light stimuli was equalized according to Michelson and Weber contrast measures, so that results can be compared to a variety of previous studies. Basic variables such as stimulus duration or background luminance were then systematically varied to test for their influence on the size/direction of the polarity effect. Our results confirm the general impression that the effect is rather unstable and occurs only in very specific experimental setups. This leads us to question the practical relevance of contrast polarity in applied settings.

◆ **Spatial filtering vs edge integration: comparing two computational models of lightness**

142 **perception**

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The goal of computational models of lightness perception is to predict the perceived lightness of any surface in a scene based on the luminance value at the corresponding retinal image location. Here, we compare two approaches that have been taken towards that goal: the oriented difference-of-Gaussian (ODOG) model [Blakeslee and McCourt, 1999, Vision Research, 39(26): 4361–4377], and

a model based on the integration of edge responses [Rudd, 2010, Journal of Vision, 10(14): 1–37]. We reimplemented the former model, and extended it by replacing the ODOG filters with steerable pyramid filters [Simoncelli and Freeman, 1995, IEEE, ICIP proceedings, 3], making the output less dependent on the specific spatial frequencies present in the input. We also implemented Rudd's edge integration idea and supplemented it with an image-segmentation stage to make it applicable to more complex stimuli than the ones he considered. We apply both models to various stimuli that have been experimentally used to probe lightness perception (e.g. disk-annulus configurations, White's illusion, Adelson's checkerboard). The model outputs are compared relative to human lightness responses. The discrepancies between the models and the human data can be used to infer those model components that are critical to capture human lightness perception.

POSTERS : CLINICAL VISION (OPHTHALMOLOGY, NEUROLOGY AND PSYCHIATRY)

◆ **Visual Performance of Highly Myopic Young Male Military Conscripts of Singapore**

143 M H M Tan, H A Yang, L K F Tey (DSO National Laboratories, Singapore; e-mail: tmeihui@dso.org.sg)

Most studies postulated the effects of visual degradation with increasing severity of myopia and axial elongation as the result of increased optical aberrations, reduced retinal sampling due to retinal stretching and/or spectacle minification resulting from myopia correction. The objective of this study is to evaluate the visual performance of highly myopic conscripts (spherical equivalent (SE) <=-6.00D) using high-contrast logMAR letters charts and super vision test-night vision goggle filter (SVT-NVG) under mesopic and simulated NVG conditions, and correlate their visual performance with refraction and axial length (AL). It was found that monocular visual acuity (VA) and contrast sensitivity (CS) deteriorated with increased myopia and AL ($p<0.05$ for all visual tests). The differences between the highly myopic subgroups and the controls were more distinct with SVT-NVG under mesopic and NVG conditions. In multivariate analysis with age and ethnicity adjustment, mesopic VA was negatively associated with SE (B=-0.022, 95%CI [–0.025, -0.019], standardised ß=-0.886, P<0.01) and AL (B=-0.019, 95%CI [-0.026, -0.012], standardised ß=-0.345, P<0.01); CS was positively associated with SE (B=0.045, 95%CI [0.035, 0.055], standardised ß=0.689, P<0.01) and AL (B=0.039, 95%CI [0.017, 0.060], standardised ß=0.267, P<0.01). • [Strang et al, 1998, Vision Research, 38:1713-1721], • [Chui et al, 2005, Vision Research, 45:593-605].

◆ **Reversal frequency of ambiguous figure in myopes and emmetropes**

144 A Kurtev, C Pan, M Awan (Physiology, Saba University School of Medicine, Netherlands Antilles; e-mail: akurtev@saba.edu)

Myopic subjects in certain visual tasks might allocate attention more narrowly than individuals with normal eyesight (McKone et al, 2008, Perception, 37, 1765-1768). Top-down processing of ambiguous figures involves direct attention and therefore, due to committing more attentional resources to the centrally presented stimulus, may lead to different perceptual effects in myopic as compared to emmetropic subjects. We studied this possibility by measuring the reversal rate of a Necker cube under two luminance levels (low photopic and high mesopic) and using positive and negative contrast for the cube outline. Each presentation condition was preceded by adaptation period for the corresponding luminance level followed by central presentation of the Necker Cube until 25 reversals were experienced. The experimental procedure was controlled by SuperLab Stimulus Presentation System (STP100W). The results showed a trend for higher reversal rate in myopic as compared to emmetropic subjects. The presentation conditions produced significant effect that was more pronounced in myopic subjects and seemed to be dependent more on order of presentation than on actual stimulus parameters. The results are interpreted as supporting the concept of different attention strategy in myopic subjects that might affect the reversal frequency and dependence of the response on stimulus presentation conditions.

◆ **Visual acuity measurement: Account of the optotype structure**

145 G Rozhkova, D Lebedev (IITP Russ Acad Sci, Russian Federation; e-mail: gir@iitp.ru)

Many optotypes used nowadays for visual acuity measurements were created without analysis of information processing that underlies subject's decision making during examination. In the cases of complex optotypes, such analysis requires taking many functional modules into account. We studied some theoretical aspects of measuring visual acuity with simple optotypes – 3-bar resolution targets – in the task of orientation discrimination. Earlier, in our experiments, we found 3 types of psychometric

functions indicating that some subjects were capable to use the low-frequency information (LFI) contained in the Fourier spectra of the optotypes while other subjects either ignored LFI or misused it (Rozhkova et al., 2012 Sensory Systems 26(2) 169-171). The new experiments carried out in conditions of presenting single stimulus line and starting from the smallest size, have shown that, at the beginning of examination, the naïve subjects often misuse LFI but, later, use it properly. For modeling subject's behavior, we developed a mathematical model of orientation discrimination mechanism describing visual stimulus transformations from the optical retinal image to the neuronal one on the basis of Gabor filters and implying a possibility of creating autonomous low-frequency and high-frequency neuronal images.

◆ **Computer-aided methods for clinical stereo acuity measurement: Some practical aspects of**
146 **left-right image separation techniques**

M Gracheva (IITP Russ Acad Sci, Russian Federation; e-mail: mg@iitp.ru)

Current computer-aided methods for presenting test stereo images imply generation of left and right images on one display and employment of some image separation techniques. Until recently, most investigators used temporal or color separation principles requiring shutter-glasses or color filters. At present, it seems more rational to use the polarization principle. As concerns the techniques based on shutter-glasses, the main deficiencies are often caused by ambient illumination (flickering in the case of gas-discharge lamps) and synchronization device. As concerns color separation technique, its deficiency was revealed but only after testing in parallel with polarization technique. To get comparable data, we used 3D display that makes possible to employ both color and polarization techniques of image separation in similar conditions. Correspondingly, in one series of measurements, left and right images were presented in anaglyphic form; in another series, left and right images were presented on differently polarized rows of pixels. The results obtained in ten subjects with polarization techniques in the range of frequencies 2-8 cpd appeared to be significantly better. This superiority suggests that difference in color between left and right images might exert essential negative effect on detecting threshold disparities. [Supported by the Program of DNIT Russ Acad Sci.]

◆ **Automatic retinal vessel extraction from fundus images taken from patients with diabetes**
147 S Holm, G Russell, N McLoughlin (Faculty of Life Sciences, University of Manchester, United Kingdom; e-mail: niall.p.mcloughlin@manchester.ac.uk)

We present here a novel database of retinal fundus images for the automatic extraction of retinal surface vessels. In contrast to other publicly available databases such as the DRIVE [Staal et al, 2004, IEEE Trans Med Imaging, 23, 501-509] or STARE database [Hoover et al, 2000, IEEE Trans Med Imaging, 19, 203-210], our database consists of only fundus images recorded from patients with diabetes. As the incidence of diabetes is increasing worldwide [Zimmet et al, 2001, Nature, 414, 782-787], screening patients for diabetic retinopathy is becoming a more onerous task. In addition to diabetes, these patients showed various pathologies such as age-related macular degeneration, hypertension and/or glaucoma. Therefore, our database is divided along the lines of retinal pathology. All these images were obtained from a diabetic retinopathy screening programme. Either a Canon CR DGi, a Topcon NW6S, or a Topcon NW8 fundus camera were used to capture the retinal images with a field of view of 45 degrees. Two separate unsupervised vessel extraction methods [Holm and McLoughlin, 2012, Perception, 41 ECVP Supplement, 103] were applied to this novel database and compared to the manually segmented images.

◆ **Zollner and Poggendorff illusions in children with ophthalmopathology.**
148 S Rychkova, A Bolshakov (IITP Russ Acad Sci, Russian Federation; e-mail: lana.rych@mail.ru)

In the previous research (Ninio and O'Regan, 1999 Perception 28 949-964) the characterisation of the misalignement and misangulation components in the Poggendorff and corner-Poggendorff illusions were studied in adult subjects with normal vision. The aim of our study was to compare age dynamics of the perception of the Zollner and classic Poggendorff illusions in children with ophthalmopathology. In total, 141 subjects aged 8-11 yrs (55 subjects), 12-14 yrs (47 subjects) and 15-18 (39 subjects) with various visual impairments (optic nerve atrophy, amblyopia, retinopathy, high myopia, astigmatism, nystagmus) were tested. The control group consisted of 17 subjects aged 16-18 yrs without ophthalmopathology. Using a nulling method, we measured the misalignement components in the Zollner and Poggendorf illusions varying stimulus orientation. The estimates of both illusions were minimal (0,5±0,04o) at the horizontal and vertical orientations, having peaks (9,1±0,09o) at the oblique orientations. We did not find significant differences in the characteristics of the illusions between different age groups and

between the children with the congenital low visual acuity (0,18±0,04 decimal units) and the children with relatively high visual acuity (0,75±0,08 decimal unit) as well. Meanwhile, the severity of illusions in all three age groups with ophthalmopathology was greater than in control subjects.

◆ **A Spatial Model of Visual Fields with Applications to Adaptive Sampling**

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Visual fields (VFs), the spatial array of perimetric sensitivity, are frequently assessed in vision research and ophthalmology to diagnose the functional loss related to diseases like glaucoma. In clinical practice, VFs are typically measured with automated perimeters that return sensitivities for a set of isolated locations, that ignore the spatial structure of VFs. In addition, the reliability of the VF test is only estimated by global indices, e.g. false positives/negatives, but not specified for individual locations. Here, we introduce a spatial probability model of VFs that transforms any set of discrete measurements into a continuous probability distribution that extends over the whole region of interest. The model includes a measure of credibility for each VF location and takes into account the noise distribution at each location and the connectivity strength among locations in the VF. These parameters can be used online to increase the efficiency of adaptive testing. Our model is designed to be used for medical diagnoses over the ratio of marginal likelihoods (Bayes Factors) and for the quantification of VF loss progression over the Kullback-Leibler divergence. The model can specifically address the diagnosis of different eye diseases. We show an application to glaucoma as a proof of concept.

◆ **Assessment of human visual pathways with simultaneous multifocal recordings from retina**

150 **and cortex**

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Simultaneous multifocal recordings of electroretinogram (mfPERG) and visual evoked potentials (mfVEPs) to pattern-reversal stimulation might allow a detailed assessment of the relationship of ganglion-cell damage and visual field defects in a direct and objective manner. We here assessed the causes of the inter-individual amplitude variability. Using VERIS Science, 21 controls (aged 21-80, 8 male) and 9 patients with primary open angle glaucoma (aged 36-80, 4 male) mfPERGs and mfVEPs were recorded monocularly for 36 visual field locations of a circular dartboard pattern (22 deg diameter). Quantitative analyses were based on mfPERG amplitudes and mfVEP signal-to-noise-ratios (SNRs). Separately conventional steady-state PERGs (ssPERG) were obtained. MfPERG amplitudes correlated with PERG amplitudes, but not with mfVEP-SNRs. Only mfPERG and ssPERG correlated negatively with age ($p<0.003$). Especially age-adjusted mfPERG-N95-amplitudes were reduced in glaucoma compared to controls. For ssPERGs a potential for early detection of glaucoma has previously been demonstrated. The covariability of mfPERG and PERG suggests retinal ganglion cells as common generators and it is related to participants' age. Consequently, combined mfPERG/mfVEP investigations might serve as a tool to uncover the relationship of retinal ganglion cell damage and visual field defects. An age correction of the retinal responses is indispensable for this purpose.

◆ **The Effect of Unilateral Glaucoma on Eccentricity Mapping within the Human Visual**

151 **Cortex**

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There is evidence that the neurodegenerative effects of glaucoma are not restricted to the optic nerve but extend to the visual cortex. However, very little is known about the effects of glaucoma on visual cortex function. We used functional magnetic resonance imaging to investigate this question in 5 adult patients with unilateral primary open-angle glaucoma. We assessed whether regions of V1 and V2 with lost input from the glaucomatous eye had a greater response to input from the fellow eye than regions receiving input from both eyes. We also assessed whether there were differences in the retinotopic maps within V1 and V2 when patients viewed through their glaucomatous versus their fellow eye. We found no evidence for an increased response to the fellow eye in glaucoma-effected regions of the cortex; however, there was a pronounced loss of activation in both V1 and V2 when patients viewed through

their glaucomatous eye. Despite this reduced activation, visual cortex responses were still evident for glaucomatous eye viewing and the eccentricity mapping of these responses was shifted towards the fovea relative to maps obtained under fellow eye viewing. These results indicate that glaucoma may influence eccentricity mapping within the visual cortex.

◆ **Retinal Dystrophy and Functional Organization of Visual Cortex in Retinitis Pigmentosa**

152 S Ferreira[1], A Pereira[1], B Quendera[1], C Mateus[1], M D R Almeida[2], E Silva[3], M Castelo-Branco[1] ([1]IBILI, Faculty of Medicine, University of Coimbra, Portugal; [2]CNC, University of Coimbra, Portugal; [3]Ophthalmology, University Hospital of Coimbra, Portugal; e-mail: soniamgaf@gmail.com)

Retinitis Pigmentosa (RP) is an inherited retinal disease characterized by progressive degeneration of photoreceptors and consecutive loss of peripheral vision. This study aims to determine the influence of rod-cone dystrophy on visual cortical function. Brain images from two RP subjects (one female; 43.50±9.19 yr) and four age- and gender-matched controls were acquired with a 3T magnetic resonance scanner and analyzed with BrainVoyager®. BOLD responses resulted from the monocular presentation of a sequence of two checkerboard rings (central and paracentral; maximum diameter of 9.52 degrees), during passive viewing and a one-back task. Visual field diameter was < 23 degrees and corrected visual acuity was > 4/10 for RP subjects. RP subjects showed significant peripheral retinotopic activation in striate and extrastriate visual areas for paracentral rings, between task and passive viewing conditions ($p<0.05$, uncorrected). Given that rings sequences were equal in both conditions, this difference in activation arose from task demands, not from passive visual stimulation. Results show a functional reorganization of visual cortex in RP subjects, as suggested by previous studies [Poggel et al, 2007, IOVS, 48(5), 935; Masuda et al, 2010, IOVS, 51(10), 5356-5364]. We propose that visual attention boosts activity in peripheral representations under active task demands in RP.

◆ **Cortical reorganization upon peripheral visual loss in Retinitis Pigmentosa**

153 A Pereira[1], S Ferreira[1], B Quendera[1], C Mateus[1], M D R Almeida[2], E Silva[3], M Castelo-Branco[1] ([1]IBILI, Faculty of Medicine, University of Coimbra, Portugal; [2]CNC, University of Coimbra, Portugal; [3]Ophthalmology, University Hospital of Coimbra, Portugal; e-mail: aspereira@fmed.uc.pt)

Retinitis Pigmentosa (RP) is a retinal disease characterized by photoreceptor degeneration. Symptoms are early onset night blindness followed by progressive loss of peripheral vision, and eventually leading to complete blindness. Using MRI we studied the impact of peripheral vision loss on cerebral cortex anatomy. Six patients (two females, 42.8±4.1 yrs) and six age- and gender-matched controls were scanned in a 3T Siemens scanner. Brain cortical thickness (CT) and surface area (SA) of Brodmann areas (BA) were obtained using Freesurfer and exported for statistical analysis with SPSS. Patients' and controls' hemispheres (n=12 per group) were compared. Patients' visual capacity ranged from peripheral visual loss (22º of maximum visual field) to blindness, with loss of central acuity. Disease duration ranged from 20 to 50 years. Visual cortical CT was preserved in patients although BA 18 (secondary visual cortex) showed a tendency for smaller SA ($p=0.058$). Importantly, patients' BA4p (primary motor cortex) showed significantly increased CT ($p=0.015$). Our results suggest a surprising link between peripheral visual loss and motor cortical alterations in RP. These results suggest compensatory motor cortical reorganization triggered by peripheral visual function loss. These results are consistent with peripheral visual sensitivity relevance in vision for action dorsal stream loops.

◆ **FMRI evidence for perceptual filling-in in patients with macular dystrophy**

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Patients with macular dystrophy often report that they are unaware of their central scotoma, suggesting the presence of perceptual filling-in. We used functional Magnetic Resonance Imaging (3 Tesla fMRI) to determine possible neural correlates of perceptual filling-in in patients with retinal dystrophy and central scotomata in both eyes. Fixation behaviour and perimetry were measured with a Nidek microperimeter. We stimulated the central visual field (30°) with low spatial frequency, squarewave gratings with three orientations (10°, 70°, 130°) that were either a) continuous, or b) were interrupted by a central grey disk. The disk was either slightly larger than the scotoma (detectable on 75% of trials) or slightly smaller (detectable on 25% of trials). To control for attention participants responded in a one-back task with respect to the grating orientation. Results indicate that patients exhibit fMRI signal increases in

retinotopic visual cortex and these signals were higher during filling-in (no disk: 0.08 %SC, small disk: 0.09 %SC, large disk: 0.02 %SC), and that classification in the foveal projection zone is above chance levels. Ongoing SVM analysis suggests higher classification rates in the foveal projection zone during filling-in conditions.

◆ **Perceptual learning in patients with central scotomata due to hereditary and age-related macular dystrophy**

155 K Rosengarth[1], C Schmalhofer[1], M Goldhacker[1], T Plank[1], S Brandl-Rühle[2], M W Greenlee[1] ([1]Institute for Experimental Psychology, Universität Regensburg, Germany; [2]Department of Ophthalmology, University Medical Center Regensburg, Germany; e-mail: katharina.rosengarth@psychologie.uni-r.de)

Hereditary and age-related forms of macular dystrophy (MD) lead to loss of cone function in the fovea, leading to eccentric fixation at the co-called preferred retinal locus (PRL). We investigated whether perceptual learning enhances visual abilities at the PRL. We also determined the neural correlates (3-Tesla fMRI) of learning success. Eight MD patients (five with age-related macular dystrophy, three with hereditary macular dystrophies) were trained on a texture discrimination task (TDT) over six days. Patients underwent three fMRI sessions (before, during and after training) while performing the TDT task (target at PRL or opposite PRL). Reading speed was also assessed before and after training. All patients showed improved performance (i.e. significant change in stimulus onset asynchronies, hit rates and reaction times) and increased reading speed after perceptual learning. We found an increase in BOLD response in the projections zone of the PRL in the primary visual cortex in six of eight patients after training. The change in fMRI signal correlated with the patients' performance enhancements. The results suggest that perceptual learning is a useful measurement in interventions for MD patients.

◆ **Visual object memory in patients with age-related macular degeneration**

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Allocation of visual attention is crucial for encoding items into visual memory. In free vision, attention is closely linked to the center of gaze. Here, we ask whether foveal vision loss entails sub-optimal deployment of attention, in turn impairing encoding of visual objects. We investigated visual memory for everyday objects in patients suffering from foveal vision loss due to age-related macular degeneration (AMD) with a change detection paradigm [Hollingworth, 2003, Journal of Experimental Psychology. Human Perception and Performance, 30, 519-537]. A highly salient cue preceded recognition before potential object manipulation, drawing attention either to a valid or an invalid target position. Patients performed the task with their worse eye (n=13) and binocularly (n=17) and were compared to matched normal-sighted controls. Controls' recognition performance was significantly enhanced for valid compared to invalid cues. Patients showed this effect only under binocular viewing and recognition performance for valid cues decreased significantly with increasing visual impairment. Recognition performance for invalid cues was comparable across all groups and not significantly related to visual impairment. It is concluded that visual object encoding into visual short-term memory (valid cues) is less efficient in AMD patients, whereas visual long-term memory (invalid cues) for visual objects remains largely intact.

◆ **Functional and structural brain modifications induced by oculomotor training in patients with age-related macular degeneration**

157 T Plank[1], K Rosengarth[1], I R Keck[1], S Brandl-Rühle[2], J Frolo[1], K Hufendiek[2], M W Greenlee[1] ([1]Institute for Experimental Psychology, University of Regensburg, Germany; [2]Department of Ophthalmology, University Medical Center Regensburg, Germany; e-mail: tina.plank@psychologie.uni-r.de)

Patients with age-related macular degeneration (AMD) are reliant on their efficient use of the peripheral visual field. Oculomotor training can help them to find the best suited area on intact peripheral retina to efficiently stabilize eccentric fixation. In this study nine patients with AMD were trained over a period of six months to improve their fixation stability. Seven healthy age-matched subjects, who did not take part in training, were used as a control group. During the six months of training the AMD subjects and the control group took part in three functional and structural magnetic resonance imaging (MRI) sessions to assess training-related changes in the brain function and structure. AMD patients benefited

from the training as indexed by significant improvements in their fixation stability, visual acuity and reading speed. The patients showed a significant positive correlation between brain activation changes in the visual cortex and improvements in fixation stability. We also found a significant increase in gray and white matter in the posterior cerebellum after training in the patient group. Our results indicate that functional and structural brain changes are associated with benefits from oculomotor training in AMD patients with central scotomata.

◆ **Measuring oculomotor stability during the assessment of image distortions with Iterative**
158 **Amsler Grid (IAG)**

I Ayhan[1], T Holmes[2], J Zanker[3] ([1]Department of Psychology, Royal Holloway, United Kingdom; [2]Acuity Intelligence Ltd, United Kingdom; [3]Department of Psychology, Royal Holloway University of London, United Kingdom; e-mail: j.zanker@rhul.ac.uk)

Metamorphopsia is experienced in age-related macular degeneration (AMD), as the perceived distortions of straight contours. The standard clinical tool to assess metamorphopsia is the printed Amsler Chart, a grid of equally spaced horizontal and vertical lines, in concunction with patients' report of deformed and irregular appearance. We developed an iterative procedure (IAG), to obtain a reproducible map of visual deformations. Curved horizontal and vertical lines segments (perceived or physical distortions) are displayed on a computer monitor to probe different regions of the visual field and then manipulated by observers such that they appear straight. Control participants were able to reliably correct deformations that simulate metamorphopsia. Pilot experiments involving AMD patients suggest that they are comfortable using the IAG method and generate sensible deformation maps, but also indicate that stabilising gaze can be difficult for them. In our current work we measure the gaze positions of control participants (Tobii X120 eye tracker). We observe that in the IAG the ability to maintain fixation in the centre of the display varies with the distance to the adjusted segment, suggesting that the gaze control can be reliable enough to manipulate lines in extra-foveal positions, to assess distortion maps in the central visual field.

◆ **Differential effects of age-related macular degeneration on retinal and cortical responses**
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A Herbik, J Reupsch, M B Hoffmann (Ophthalmic Department, Otto-von-Guericke-University Magdeburg, Germany; e-mail: anne.herbik@med.ovgu.de)

Objective: To assess the relationship of retinal and cortical responses in age related macular degeneration (AMD), we determined the dependence of multifocal electroretinograms (mfERGS) and multifocal visual evoked potentials (mfVEPs) on visual acuity. Methods: Using VERIS Science 5.01.12X (EDI, CA, USA) separate monocular pattern-reversal mfVEP (46 deg diameter; 60 visual field patches in 5 eccentricity ranges) and flash mfERG (49 deg diameter; 103 visual field patches in 7 eccentricity ranges) recordings were obtained from 17 participants with AMD. Average mfERG amplitudes (P1-peak) and mfVEP-signal-to-noise-ratios (SNRs) were calculated for each eccentricity and correlated with logarithmised visual acuity. Results: Visual acuities ranged between 0.06 and 1.00 (median 0.63). While mfVEP-SNRs correlated with visual acuities for two most central eccentricities 0.6 deg ($r = 0.65$, $p = 0.025$) and 2 deg ($r = 0.71$, $p = 0.006$), but not the more peripheral 3 eccentricities. No correlations with visual acuity were observed for mfERG amplitudes. Conclusions: A differential effect of AMD on retinal and cortical responses was observed. Although mfERGs measure the responses directly at the site damaged in AMD, ie. the retina, cortical responses were more closely related to the variation of functional deficits associated with AMD.

◆ **Does perisaccadic compression require foveal vision?**
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People make systematic errors when localizing a stimulus that is presented briefly near the time of the saccade. These errors have been interpreted as a compression towards the fixation position at the end of the saccade. Normally, the fixation location is the position that falls on the fovea. Macular Degeneration (MD) damages the central retina often obliterating foveal vision. MD patients typically adopt a new retinal locus for fixation, in the periphery, called the preferred retinal locus (PRL). If the compression of space during the saccade is a special characteristic of the fovea, perhaps due to the high density of cones that is found in the fovea, one might expect people lacking central vision to show no compression of space around the time of a saccade. If the compression of space is related to fixation, one might expect similar compression towards the PRL, despite the lack of a high density of cones in this area. We

found that a MD patient showed a clear compression towards the PRL. We conclude that perisaccadic compression does not require a high density of receptors in the fovea.

◆ **Spatio-temporal correlates of interocular suppression in amblyopia**

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A growing body of evidence suggests that normal binocular interactions are still present in amblyopic adults. Here we examined the spatio-temporal neural correlates of interocular suppression in 11 amblyopic adults and 12 controls by recording steady-state high-density (64 channels) EEG using a flash suppression paradigm. The degree of suppression was manipulated by changing the contrast of the "flash" stimulus. At the behavioural level, the flash suppression effect was found in both groups when the dominant eye suppresses the non-dominant eye. Interestingly, the reverse suppression effect was also observed such that the amblyopic eye suppressed the response of the dominant eye. At the EEG level, spectral analysis and current source density (CSD) topographies revealed maximal suppressive response over the occipital cortex (Oz) with similar amplitude and time course in both groups. Suppression EEG responses occurred from 200 to 500 ms after the onset of the flash suppressive stimulus and was delayed as a function of contrast. Although more research is need to be conducted, our findings indicate that the mechanisms of interocular flash suppression in amblyopia are not qualitatively abnormal, suggesting the existence of functional binocular interaction in adult amblyopia.

◆ **Perceptual visual distortions in amblyopia and their stability over time**

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It is well-established that amblyopes experience metamorphopsia (spatial visual distortions) (Lagreze and Sireteanu, 1991, Vision Research, 31, 1271-1288). Metamorphopsia measured with subjective sketches and shape reconstruction tasks is highly repeatable. However, its long term stability is unknown. We examined the pattern and severity of monocular and dichoptic amblyopic metamorphopsia, to determine stability one week and one month after initial assessment. 6 adult amblyopes and 3 age-matched controls had visual acuity and binocular vision assessments. At each visit, monocular metamorphopsia was measured 4 times in each eye (computerised square-reconstruction task), and dichoptic metamorphopsia 5 times binocularly (mouse-based target-clicking task on a stereoscopic LCD monitor, using active shutter glasses). Controls had no significant metamorphopsia – this did not change over time (dichoptic, $p = 0.074$; monocular, $p = 0.920$). Amblyopes showed metamorphopsia compared to controls (dichoptic, $p < 0.001$; amblyopic eye, $p = 0.005$), but no significant change in dichoptic ($p = 0.786$) or monocular (amblyopic eye, $p = 0.061$) metamorphopsia over time. Our method measured binocular and monocular metamorphopsia in amblyopic participants and demonstrated that pattern/severity was stable over one month. This consistent metamorphopsia exists in treated and untreated amblyopes and could potentially influence the outcomes of existing and emerging amblyopia treatments.

◆ **Model simulation of the SSD task for a patient with lesioned thalamus**

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Our research studies why we perceive our external environment as stable although the retinal image changes with every eye movement. Particularly, we aim to explain why small displacements of visual targets cannot be detected if the displacement takes place during the eye movement, a phenomenon called saccadic suppression of displacement (SSD) [Deubel et al, 1996, Vision Res, 36(7):985-996]. Many experiments suggested an explanation through predictive remapping [Duhamel et al, 1992, Science, 255(5040):90-92] and corollary discharge signals [Sommer&Wurtz, 2008, Annu Rev Neurosci, 31:317-338]. Recently, Ostendorf [Ostendorf et al, 2010, Proc Natl Acad Sci USA 107(3):1229-1234] presented data of a patient with a right thalamic lesion showing a bias towards perceived backward displacements for rightward saccades in the SSD-task. To better understand the nature of the behavioral impairment following the thalamic lesion we applied a computational model developed by Ziesche and Hamker [Ziesche&Hamker, 2011, J Neurosci, 31:17392-17405] to simulate the patient. As the patient shows normal saccade targeting scatter, our model simulations indicate that an internal eye position signal is not correctly represented, i.e. it shows a bias and is noisier compared to normal subjects. Impairments in

corollary discharge and predictive remapping mechanisms are not necessarily required to explain the behavioral data.

◆ **Electroencephalographic index of spatial attention shift following multisensory stimulation**
164 **training for hemianopia**

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Hemianopia is a homonymous visual field deficit, resulting from posterior cortical lesion, which can contribute towards inefficient eye-saccades in the hemianopic visual field. Here we present evidence that this inefficient eye movement behaviour may be at least in part a function of post-lesion hyperactivation of the intact hemisphere, with concurrent hypoactivation of the damaged hemisphere; i.e., patients focus their attention on the ipsilesional field and the contralesional field lacks sufficient attentional resources. In the present data, we observed that by stimulating the collicular-extrastriate pathway (known to contribute to spatial orienting behaviours) with a multi-sensory training paradigm, visual oculomotor exploration improved in a sample of seven hemianopia patients; this improvement allowed patients to compensate for the loss of vision with more efficient eye saccades. In addition, amplitudes of P3 event related potentials elicited by a simple visual detection paradigm were significantly reduced after the treatment when the stimuli were presented to the intact field. One interpretation of the behavioural improvement in the hemianopic field, and concurrent ERP amplitude reduction in the intact field, might be a shift in spatial attention away from the hyperactivated intact visual field.

◆ **Visual perceptual abilities after perinatal and early childhood strokes**
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Stroke is a considerable cause of mortality and chronic morbidity in children. Incidence rates for ischemic stroke range from 300 to 500 cases per year in Germany. Deficits in visual perception resulting from infantile strokes are common but difficult to diagnose due to post-lesional cortical adaptation. The study aimed to characterize deficits in the processing of visual stimulus configurations in children suffering from perinatal or early childhood stroke (n = 31, between 9 and 21 years of age) using the German version of the Developmental Test of Visual Perception – Adolescent and Adult (Petermann, Waldmann & Daseking, 2012). Our results show significant performance differences in various levels of visual perception compared with an age-matched control group. Thus it seems highly necessary to precisely diagnose potential perceptual inabilities caused by early childhood stroke in order to apply individual therapeutic interventions.

◆ **Specific vs. unspecific long-term deficits of intermediate visual perception after stroke**
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Lesions of human visual association cortex can result in achromatopsia, akinetopsia, or other specific impairments of visual recognition. Patients with unilateral stroke of occipito-temporal cortex and intact visual fields (as proven by standard perimetry) show large inter-individual differences in the pattern of impairment when tested psychophysically in different visual sub-modalities [Grimsen et al., 2011, Perception, 40 ECVP Supplement, 43]. For forty patients with chronic damage of visual cortex we determined perceptual thresholds for each quadrant of the visual field in four different visual modules (luminance, colour, texture, motion). Thresholds were normalised and corrected for age (control group, n = 60). More than 40% of the patients had significantly increased thresholds. The deficits were more pronounced in visual form discrimination than for detection, but unspecific for individual visual sub-modalities. But in both, patients and controls, we found only minor correlations between performance in different modules, indicating little correlation between visual sub-functions. These findings show that 1) intermediate visual perception is disturbed in a sizeable number of our patients in spite of intact visual fields, 2) chronic deficits are relatively unspecific for modality and 3) deficits may be caused by impaired grouping/segmentation mechanisms on a higher processing stage.

◆ **Neural changes in early visual cortex after unilateral occipito-temporal stroke and**
167 **object-recognition deficits**

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Visual object agnosia is a striking symptom following bilateral lesions of occipito-temporal cortices. After unilateral ventral lesions usually no major object recognition deficits occur. We used fMRI to investigate eight stroke patients with unilateral occipito-temporal damage and free visual fields to assess object-categorization performance and corresponding neural correlates. Patients and controls performed a rapid event-related paradigm (animal/non-animal categorization), with images presented left or right of fixation. Lateralized stimulus presentation normally elicits higher cortical activation for contralateral than ipsilateral stimuli (contralateral bias). Regions of interest in early and object-selective visual cortex were delineated using separate mapping paradigms. Previously, we showed that patients yield reduced categorization performance both ipsi- and contralesional, accompanied by altered BOLD responses in object-selective cortex of the lesioned hemisphere (no contralateral bias; Prass et al., 2012, Perception, 41 ECVP Supplement, 104). Here, we report how activity in undamaged early visual cortex is modulated: early areas of the lesioned hemisphere show a reduced contralateral bias. The intact hemisphere was normally activated. The results demonstrate that patients with unilateral lesions and object categorization deficits in both visual fields show altered neural activation even in early (undamaged) visual areas. This suggests that ventral lesions remotely influence structurally intact early visual cortex.

◆ **Electrophysiological examination of patient with partial recovery of vision after 53 years of**
168 **blindness**

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72-year-old subject KP lost his sight at the age of 17 years, and light projection onto his right retina was restored after 53 years of visual deprivation by a corneal implant. Nine months after sight recovery we had opportunity to examine his vision using electrophysiology tests assessing the effect of long-term deprivation on a mature visual system. In spite of degraded vision and sensory deprivation lasting 53 years and partial retinal detachment we recorded reliable and reproducible responses to all used stimuli after their adjustment to KP's vision. The KP's responses were compared to results of two age matched control subjects, to whom the stimuli were adjusted in size and contrast to mimic KP's vision. Both VEP variants were significantly delayed in comparison to the controls' responses. However, the KP's time interval between sensory detection and the cognitive component (P3b/P300) of the ERP to a target event in the visual oddball paradigm was not further delayed. Long-term visual deprivation and retinal detachment degraded KP's electrophysiological markers of visual sensory processing, whereas the cognitive processing of appropriate visual stimuli was not compromised (Kremlacek J et al., Vis Research, 2013).

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◆ **Delayed visuomotor performance is not generally impaired in visual form agnosic patient**
169 **DF**

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It was suggested that while movements directed at visible targets are processed within the dorsal stream, movements executed after delay rely on the visual representations of the ventral stream [Milner and Goodale, 2006, The Visual Brain in Action, Oxford, University Press]. This interpretation was supported by the observation that a patient with ventral stream damage (DF) has trouble performing accurate movements after a delay, but performs normally when the target is visible during movement programming. We tested DF's visuomotor performance in a letter-posting task whilst varying the amount of visual feedback available. Additionally, we also varied whether DF received haptic feedback at the end of each trial (posting through a letter box vs. posting on a screen) and whether environmental cues were available during the delay period (removing the target only vs. suppressing vision completely with shutter glasses). We found that DF's visuomotor performance was only impaired in conditions in which the target was removed from view while the surrounding environment remained visible. We suggest that

in these conditions, healthy participants can resort to cues from the visual environment to compensate for the withdrawal of target information. These cues are allocentric in nature and therefore presumably not available to DF.

◆ **Voice Perception in Prosopagnosia**

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Right or bilateral anterior temporal damage can impair face recognition, while leaving face discrimination relatively intact. While this is often considered an associative type of prosopagnosia, similar lesions can also cause a multimodal person-specific semantic disorder. Although many subjects claim that they can still recognize people by voice, this has seldom been tested formally. We developed a new face and voice discrimination test. For face discrimination, a neutral target face is followed by two smiling choice-faces, and subjects identify which choice-face matched the target. For voice discrimination, a target voice reading a short sentence is followed by two choice-voices reading a different sentence, and subjects identify the choice-voice that matched the target. In 22 healthy subjects, we found that performance had good testing characteristics, with results that were not at ceiling and which had low variance. In one prosopagnosic subject with bilateral fusiform lesions we found impaired face discrimination but preserved voice discrimination. Two prosopagnosic subjects with anterior temporal lesions had preserved discrimination of both voices and faces, despite impaired face recognition on other tests. These findings show that discrimination of voices is intact after either anterior temporal or fusiform lesions in patients with impaired face recognition.

◆ **Intranasal Inhalation of Oxytocin Improves Face Processing in Developmental**

171 **Prosopagnosia**

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Developmental prosopagnosia (DP) is characterised by a severe, lifelong impairment in face recognition. Little work has attempted to improve face processing in these individuals, but intriguingly, recent evidence suggests oxytocin can improve face processing in both healthy participants and individuals with autism. This study examined whether oxytocin could also improve face processing in individuals with DP. Ten adults with the condition and 10 matched controls were tested using a randomized placebo-controlled double-blind within-subject experimental design (AB-BA). Each participant took part in two testing sessions where they inhaled 24IU of oxytocin or placebo spray and completed two face processing tests: one assessing face memory and the other face perception. Results showed main effects of both participant group and treatment condition in both face processing tests, but the two did not interact. Specifically, the performance of DP participants was significantly lower than control performance under both oxytocin and placebo conditions, but oxytocin improved processing to a similar extent in both groups.

◆ **Recognition Memory in Developmental Prosopagnosia: Behavioural and**

172 **Electrophysiological Evidence for an Impairment of Recollection of Faces**

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Developmental prosopagnosia (DP) is a face perception disorder characterised by an impairment for recognising faces combined with normal intelligence and intact low level visual processing. While a deficit for recognising faces in DP is well established, the exact nature of this impairment still remains unclear. Dual-process theories of recognition memory propose two distinct mechanisms that contribute towards recognition memory performance: recollection and familiarity. The Remember/Know (R/K) procedure is thought to measure the respective contributions of recollection and familiarity to recognition performance. Previous research in DP has neglected to take into account these distinct processes when examining face recognition. We recorded electroencephalogram (EEG) activity during a R/K recognition memory task for faces in 25 controls and 10 DPs. DPs displayed an overall impairment in recognising faces which was driven by a smaller proportion of "remember" responses. EEG activity for controls and

DPs was qualitatively similar, but DPs exhibited smaller waveform differences between "remember" and correct "new" responses and across a smaller area of the scalp. These findings suggest a specific impairment of recollection (but not familiarity) of faces in DP.

◆ **The collinear flanker facilitation effects in individuals with psychoticism and creative traits**

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Individuals of schizophrenia spectrum show a deficit in perceptual organization. To understand the mechanisms underlying such deficit, we measured the collinear flanker effect on contrast discrimination in 26 observers with various degrees of psychoticism. Each observer was assessed by Eysenck Personality Questionnaire for psychoticism and Creativity Personality Scale for creative traits. The latter was to test the relationship between creativity and psychoticism. The task of the observers was to detect a 4 cyc/deg vertical Gabor target superimposed on a Gabor pedestal. We measured the target-threshold vs. pedestal-contrast (TvC) functions with or without the presence of collinear flankers. For all observers, the presence of the flankers decreased target threshold at low pedestal contrasts, but increased it at high contrasts. Compared with the control group, the high-psychoticism/low-creativity individuals showed a larger flanker effect at low contrast but a smaller effect at high contrasts. The high-psychoticism/high-creativity individuals showed an opposite trend. The individual difference in the data was well fit by a contrast normalization model by varying both excitatory and inhibitory sensitivities to the flankers but not the sensitivities to the pedestal or target. Contrasts with previous studies, our result suggests different mechanisms for psychoticism and creative traits.

◆ **Aberrant evoked and resting state EEG in schizophrenia**

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Schizophrenic patients have strong deficits in backward masking compared to controls. Masking deficits corresponded well to reduced amplitudes in the EEG, particularly, around 200ms after the stimulus onset. We located deficits mainly in the lateral occipital cortex. Are these deficits caused by stimulus induced activity only or a general dysfunction? In order to capture the complex dynamics of brain activity while rest, we recorded 5 min of eyes closed EEG in 27 patients with schizophrenia and 27 age-matched controls. We analyzed microstates, i.e. short periods (100 ms) of scalp potentials which are highly consistent across subjects and recordings. Four microstates played a major role and three of them had different durations and occurrences in patients compared to controls. In particular, these microstates relate to the salience and attention networks. As a speculation, the altered dynamics of the salience and attention networks could be responsible for the masking deficits because the briefly presented target is missed.

◆ **Neurophysiological correlates of visual backward masking deficits in schizotypy**

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Schizophrenic patients are strongly deteriorated in visual backward masking. Masking deficits are of great interest because they are stable and specific markers of the disease. Masking deficits in patients are reflected in reduced amplitudes of the EEG pointing to a diminished target representation. Recently, we showed that also unaffected students with high scores in schizotypy (cognitive disorganization) have backward masking deficits compared to students with low scores. Here, we tested healthy undergraduate students with extreme scores (high or low) in cognitive disorganisation. As schizophrenic patients, healthy students with high scores in cognitive disorganisation had diminished amplitudes in the EEG. Interestingly, high cognitive disorganisation students showed a strongly increased late component in the EEG which was not present in patients and low cognitive disorganisation student controls. This enhanced component might be related to a compensation mechanism which is not present in the patients.

Our results show further evidence that visual backward masking is a potential endophenotype of schizophrenia.

◆ **The Detection and Discrimination of Objects in Patients with Schizophrenia treated with**
176 **Atypical and Typical Drugs**

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We are study the influence of different antipsychotic drugs on the magno- and parvocellular visual channels. We measured the contrast sensitivity and magnitude of the Muller-Lyer illusion in normal observers and schizophrenic patients. We used the Gabor gratings and images of the Muller-Lyer figure after they were digitally wavelet filtered. Both types of stimuli have the same ranges of spatial frequency (0.4, 3.6 and 17.9 cycle/degree). Patients were divided into two groups. The first group consisted of patients treated with atypical antipsychotic drugs, the second group – typical drugs. In both groups of patients we see the decline of sensitivity in the range of low and medium spatial frequencies in comparison with the norm. The patients treated with the atypical drugs showed the same sensitivity to the Muller-Lyer illusion as in the norm when the arrows of stimulus were presented in low spatial frequency range, whereas the patients with the typical drugs treatment showed higher magnitude of the illusion, than healthy. We demonstrate the significant differences of sensitivity in the range of low spatial frequencies between two groups of patients. It may be a result of different selective effect of typical and atypical drugs on visual channels.

◆ **Eye movements of patients with schizophrenia in a natural environment**
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Schizophrenia is known to affect eye movements in laboratory settings. Many studies have documented e.g. a reduced gain during smooth tracking, or variations in fixation patterns between patients and controls. The question remains if at least part of the obtained results might be related to the experimental environment. Accordingly, a natural setting would be preferable for the oculomotor-testing of patients and controls. Here, we used a mobile light weight eye tracker (EyeSeeCam) to study eye movements of patients and healthy controls while freely walking in an indoor environment. Overall 20 schizophrenia patients and 20 healthy age-matched volunteers participated in the study, each performing 4 different oculomotor tasks. Patients fixated significantly more often and for a shorter time as compared to controls while looking at predefined targets. The opposite was true when participants were free to look wherever they wanted. During visual tracking, patients showed a significantly greater root-mean-square error (representing the mean deviation from optimal) of retinal target velocity. Surprisingly and different from previous results obtained in laboratory settings no such difference was found for velocity gain. Taken together, we have identified highly fundamental and quickly accessible oculomotor parameters, which might support the diagnosis of schizophrenia in the near future.

◆ **Delusions and the tilt illusion**
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Contextual processing deficits have been considered to underlie many of the cognitive impairments associated with Schizophrenia. For instance a failure of context to guide processing has been attributed to the emergence of delusional beliefs (e.g. Frith, 1979). Here we examined delusional ideation in a healthy and clinical population to examine whether the extent of one's susceptibility to the context-dependent tilt illusion relates to one's propensity to experience delusional thought. Our study reports a significant difference in tilt illusion magnitude between patients and controls, with patients exhibiting stronger repulsion effects. Furthermore, we found evidence for a significant correlation between the strength of this contextual effect and a subject's measure of delusional ideation. These results reinforce the idea of the schizotypal nervous system (e.g. Claridge and Hewitt, 1987) and the proposal that contextual processing abnormalities are the manifestation of a larger disturbance of cognitive coordination in schizotypy and schizophrenia (e.g. Uhlaas et al., 2004).

◆ **Visually induced MEG γ-band oscillations in a human pharmacological model of psychosis**

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Aberrant neural oscillations in the gamma-band range (>30 Hz) are crucially involved in the pathophysiology of schizophrenia. Dysfunctional gamma-band-activity can be driven by disrupted glutamatergic neurotransmission mediated by the N-methyl-D-aspartate (NMDA) receptor. In this study, we examined the effects of NMDA-receptor hypofunctioning on gamma-band-activity during the administration of ketamine in human participants. Neural oscillations induced by sinusoidal gratings were recorded using Magnetoencephalography (MEG) in a group of 15 healthy volunteers. We also recorded resting state activity. Each participant received an intravenous injection of a sub-anesthetic dose of ketamine and a placebo saline solution in a within-subject design. Results show that ketamine, compared to placebo, led to an increase of visually-induced gamma band oscillations (45-75 Hz) over occipital sensors, with sources localized to early visual areas. Ketamine also increased gamma-activity (30-60 Hz) at rest over fronto-central sensors, with sources localized in the right anterior cingulum and left orbito-frontal cortex. The ketamine-induced gamma-band-activity upregulation can be explained by the shift in the excitation/inhibition balance in favor of excitation of pyramidal cells due to hypofunctioning NMDA-receptor. Since the upregulation of gamma-band activity has been described in early psychosis, our results support the clinical relevance of the NMDA-receptor hypofunctioning model of schizophrenia.

◆ **From visual masking to ASD**

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Visual masking of features in a stimulus may occur when another stimulus is presented just before or after it. Post-hoc, forms of masking are defined in spatio-temporal terms - such as forward masking (or paracontrast masking if without spatial overlap, or priming in case of a negative masking effect) and backward masking (or metacontrast masking if without spatial overlap). Processing mechanisms in the visual hierarchy in the brain suggest, however, that structural relationships between both stimuli determine whether masking occurs, and if so, in which form. These mechanisms suggest (a) that global structures are represented at higher levels in the visual hierarchy, (b) that they emerge via bottom-up integration of local features represented at lower levels, and (c) that, consequently, top-down attention has to pass through global structures to arrive at local features. This mechanistic view is argued to provide a promising framework to explain masking phenomena in normal vision. Furthermore, it suggests that the "local advantage" phenomenon in ASD can be explained by (individually varying) impairments in the perceptual integration mechanism: such impairments hamper the emergence of global structures so that top-down attention has less trouble arriving at local features.

◆ **Preserved first-order configural and holistic face processing in high-functioning adults with autism: an EEG/ERP study**

181 P Tavares, S Mouga, G Oliveira, M Castelo-Branco (IBILI, Faculty of Medicine, University of Coimbra, Portugal; e-mail: pmtavares@fmed.uc.pt)

People with autism spectrum disorders (ASD) have marked deficits in the social domain, most notably in face perception. According to current models, there are at least three levels of face processing: first-order (two eyes, above a nose, which is above a mouth), second-order (the relative distance between features) and holistic (ability to recognize as faces images that lack distinctive facial features). We used event-related potentials (ERPs) in 9 high-functioning adults with ASD and 14 healthy controls, during a face decision task, using photographic, schematic and Mooney upright and inverted faces, and control scrambled images, to determine whether people with ASD are generically impaired in facial configural processing or whether this impairment is selective to specific levels of configural processing. Behaviorally, there were no differences in performance between ASD and healthy controls. At the electrophysiological level subjects with ASD displayed a normal N170 inversion effect (being significant bilaterally). Processing differences between ASD and controls in the N170 amplitude and latency obtained in Photographic, Schematic and Mooney faces could all be explained away by using IQ measures as covariates. We conclude that the ASD group shows sparing of first-order configural and holistic face processing when cognitive levels are taken into account.

◆ 182 **Perceptions of Facial Expressions of Emotion in Autism Spectrum Disorders: Reading the "minds eye" Using Reverse Correlation**

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One of the "primary social deficits" of Autism Spectrum Disorders (ASDs) is understanding the emotions of others, yet current literature is inconclusive as to whether individuals with ASD perceive basic facial expressions of emotion differently from typically developed (TD) individuals [Simmons, et al. 2009, Vision Research, 49, 12705-2739] and, if so, which specific emotions are confused. To address this question, we combined the power of subjective perception with a psychophysical technique (reverse correlation) to model the mental representations of facial expressions in high functioning (HF) ASD and TD adult participants. Participants categorized random expressions constructed using a unique 4D Facial Action Coding System-based generative face grammar [Yu et al. 2012, Computers and Graphics, 36, 152-162] into six basic emotions: happy, surprise, fear, disgust, anger and sadness (or "other"). By applying cluster analysis to the resulting facial expression models we found that TD models formed six distinct clusters, in line with the literature. In contrast, ASD models showed overlap between emotion categories, with fear and anger reflecting the lowest clarity in mental representation. These data demonstrate that even HF ASD groups have difficulties recognizing basic facial expressions of emotion.

◆ 183 **Individuals with autism spectrum disorders benefit from the addition of coloured tints when discriminating intensities of facial expressions**

L Whitaker, C R Jones, A Wilkins, D Roberson (Psychology Department, University of Essex, United Kingdom; e-mail: lwhita@essex.ac.uk)

Impairments in the processing of facial expressions often occur in individuals with autism spectrum disorder (ASD), possibly related to atypical perceptual processing and/or visual stress. An established means of reducing visual stress and improving reading speed in typically developing (TD) individuals is the use of transparent coloured tints (e.g. Wilkins, Jeanes, Pumfrey, & Laskier, 1996). Ludlow, Taylor-Whiffen and Wilkins (2012) recently found that coloured overlays improved recognition of complex emotions from the eye area in individuals with ASD. In the present study we measured judgements of emotional intensity using self-selected transparent coloured tints in 16 children with ASD (mean age=11.6) and 16 age and full-scale IQ matched TD controls (mean age=11.2). Participants judged which of two simultaneously presented faces expressed the most intense emotion for face pairs displaying anger, sadness, disgust, fear, happiness or surprise. The face pairs were presented with or without coloured tints, chosen individually as best improving the perceived clarity of text. ASD children's judgements of emotional intensity improved significantly in accuracy with the addition of coloured tints, but TD children's did not; a result that would be consistent with a link between impairments in facial expression processing and visual stress in individuals with ASD.

◆ 184 **Diagnostic and correction of visual object recognition in preschool children with Autism spectrum disorders (ASD)**

D Pereverzeva (Center of Neurobiological Diagnosis of Hereditary Mental Disorders in Children and Adolescents, Moscow State University of Psychology and Education, Russian Federation; e-mail: dasha.pereverzeva@gmail.com)

The aim of our study was to assess visual object recognition in ASD children with severe and middle learning disabilities (SLD / MLD). Twenty children with ASD (3,4 - 7 yrs), (experimental group); 10 children with Down syndrome (DS) (3,6-7 yrs), and 20 typically developing children (TD) (1,4 – 4 yrs) (control groups) were assessed with visual cognitive tests battery; Psycho-educational profile; Childhood autism rating scale. The groups were matched on psychomotor level of development. Results. 1. Participants from MLD ASD group made significantly more recognition errors than TD matches, relying on the similar geometrical shape of objects projections, and ignoring other perceptive and semantic features ($p<0,001$), and were significantly better in the identification of abstract figures. There was a positive correlation between the number of such shape-based errors and the depth of autistic symptoms. 2. The number of errors in the "geometrical shape matching" task in the SLD ASD group depended on the size of figures and was significantly higher in the "big size" trial (angular dimension of stimuli 100°) than in the "small size" trial (10°) ($p=0,005$). There was no difference between tests results in TD and DS groups. Using of yoked-prism lenses provoked improvement in shape recognition.

◆ **An early ERP signature reflects differences in visual processing between Asperger and control observers**

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Background: Asperger Autism is a lifelong psychiatric condition with problems in social cognition, highly circumscribed interests and routines and also perceptual abnormalities with sensory hypersensitivity. To objectify such perceptual alterations we looked for differences in cognitive and early visual event-related potentials (EEG) between Asperger observers and matched controls. Methods: In a typical oddball paradigm checkerboards of two sizes were presented with different frequencies. Participants counted the occurrence times of the rare stimuli. We focused early visual ERP responses and the classical late P3b component. Results: A positive ERP component, 200 ms after stimulus onset (P200) and maximal at occipito-parietal midline electrodes, showed smaller amplitudes in Asperger observers compared to controls. This difference was most prominent with small checkerboards. The rare stimuli elicited a typical odball-P3b with maximal amplitudes at central electrodes. The P3b occurred earlier for small checkerboards and this latency difference was larger in Asperger observers compared to controls. Discussion: The P200 amplitude effect may reflect principle differences in early visual processing between the Asperger observers and normal controls. These differences get more obvious with detailedness of the stimulus (e.g. more edges in smaller squares) and seem to affect the timing of later, more cognitive processing steps (P3b latency-decrease).

◆ **Visual discomfort induced by natural images in migraineurs and normal controls**

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Abstract paintings with excessive energy at medium spatial frequencies are likely to induce visual discomfort [Fernandez and Wilkins, 2008, Perception, 37(7), 1098-1113]. However, it has not been investigated that how spatial properties of natural images contribute to discomfort especially in migraineurs, who are known to be susceptible to visual discomfort [Muelleners et al, 2001, Headache, 41(6), 565-572]. In experiment 1, participants classified 122 natural images into comfortable and uncomfortable images according to discomfort to view. Consequently, we obtained five each of comfortable and uncomfortable images. The Fourier amplitude spectra of these images revealed that the uncomfortable images had higher energy at the spatial frequency of 4.0-4.7 cycles/degree (cpd). In experiment 2, migraineurs and controls rated discomfort to view the comfortable/uncomfortable images filtered to have lower energy at 4.0-4.7 cpd and the original images on a 7-point scale. Simultaneously, participants' pupil sizes were measured. Results showed that there was no difference between discomfort ratings for the comfortable and uncomfortable filtered images in both participant groups, and that the pupils of migraineurs particularly contracted when they viewed the uncomfortable original images. In conclusion, the amount of energy at 4.0-4.7 cpd in natural images contributes to visual discomfort, especially in migraineurs.

◆ **Vision in subjects with hyperawareness of afterimages and "visual snow"**

187 R Alissa[1], W Bi[1], A-C Bessero[2], G Plant[2], J L Barbur[1] ([1]Applied Vision Research Centre, City University London, United Kingdom; [2]The National Hospital for Neurology and Neurosurgery, United Kingdom; e-mail: ruba.alissa.1@city.ac.uk)

Patients complain of persisting visual noise, often described as "visual snow" (VS), but show no obvious clinical abnormalities. The aim of this study was to investigate the extent to which the processing of different stimulus attributes remains normal in VS patients. Advanced vision tests were used to assess visual acuity (VA), colour sensitivity, chromatic afterimage strength and duration and pupil response amplitudes and latencies to chromatic stimuli on nine control subjects and eight VS patients. Preliminary results show that the VS patients exhibit normal VA, colour sensitivity and chromatic afterimage strength. Both controls and four of the VS patients exhibited pupil constrictions to the onset of the coloured stimulus, followed by recovery during the stimulus and a further constriction at stimulus offset (Prog.Brain Res. 144:243-259, 2004). However, the pupil responses measured in other four VS patients showed sustained recovery phase following the initial constriction to stimulus onset. The absence of pupil recovery suggests is consistent with a more sustained signal which may be either an input from retina or feedback signals from the cortex which can also drive pupil responses. This may be linked to differences in retinal processing of visual signals that cause the perception of visual snow.

Tuesday

PLENARY SYMPOSIUM : COMPUTATIONAL NEUROSCIENCE MEETS VISUAL PERCEPTION

- **A theory of the primary visual cortex (V1): Predictions, experimental tests, and implications for future research**

L Zhaoping (University College London, London, United Kingdom)

Since Hubel and Wiesel's venerable studies, more is known about the physiology of V1 than other areas in visual cortex. However, its function has been seen merely as extracting primitive image features to service more important functions of higher visual areas such as object recognition. A decade ago, a different function of V1 was hypothesized: creating a bottom-up saliency map which exogenously guides an attentional processing spotlight to a tiny fraction of visual input (Li, 2002, Trends in Cognitive Science, 6(1):9-16). This theory holds that the bottom-up saliency of any visual location in a given scene is signaled by the highest V1 neural response to this location, regardless of the feature preferences of the neurons concerned. Intra-cortical interactions between neighboring V1 neurons serve to transform visual inputs to neural responses that signal the saliency. In particular, iso-feature suppression between neighboring V1 neurons tuned to similar visual features, such as orientation or color, reduces V1 responses to an iso-feature background, thereby highlighting the relatively unsuppressed response to an unique feature singleton. Superior colliculus, receiving inputs directly from V1, likely reads out the V1 saliency map to execute attentional selection. Several non-trivial predictions from this V1 theory have subsequently been confirmed. The most surprising one states that an ocular singleton — an item uniquely presented to one eye among items presented to the other eye — should capture attention (Zhaoping, 2008, Journal of Vision, 8/5/1). This attentional capture is stronger than that of a perceptually distinct orientation singleton. It is a hallmark of V1, since the eye of origin of visual input is barely encoded in cortical areas beyond V1, and indeed it is nearly impossible for observers to recognize an input based on its eye of origin. Another distinctive prediction is quantitative, yet parameter-free (Zhaoping and Zhe, 2012, Journal of Vision, 12(9):1160). It concerns reaction times for finding a single bar with unique features (in color, orientation, and/or motion direction) in a field of other bars that are all the same. Reaction times are shorter when the unique target bar differs from the background bars by more features; the theory predicts exactly how much. Behavioural data (collected by Koene and Zhaoping 2007, Journal of Vision, 7/7/6) confirms this prediction. The prediction depends on there being only few neurons tuned to all the three features, a restriction that is true of V1, but not of extra-striate areas. This suggests that the latter play little role in exogenous saliency of at least feature singletons. Exogenous selection is faster and often more potent than endogenous selection, and together they admit only a tiny fraction of sensory information through an attentional bottleneck. V1's role in exogeneous selection suggests that extra-striate areas might be better understood in terms of computations in light of the exogenous selection, and these computations include endogenous selection and post selectional visual inference. Furthermore, visual bottom-up saliency signals found in frontal and parietal cortical areas should be inherited from V1.

- **Models of Early Spatial Vision: Bayesian Statistics and Population Decoding**

F Wichmann (University of Tübingen, Tübingen, Germany)

In psychophysical models of human pattern detection it is assumed that the retinal image is analyzed through (nearly) independent and linear pathways ("channels") tuned to different spatial frequencies and orientations followed by a simple maximum-output decoding rule. This hypothesis originates from a series of very carefully conducted and frequently replicated psychophysical pattern detection, summation, adaptation, and uncertainty experiments, whose data are all consistent with the simple model described above. However, spatial-frequency tuned neurons in primary visual cortex are neither linear nor independent, and ample evidence suggests that perceptual decisions are mediated by pooling responses of multiple neurons. Here I will present recent work by Goris, Putzeys, Wagemans & Wichmann (Psychological Review, in press), proposing an alternative theory of detection in which perceptual decisions develop from maximum-likelihood decoding of a neurophysiologically-inspired model of population activity in primary visual cortex. We demonstrate that this model predicts a broad range of classic detection results. Using a single set of parameters, our model can account for several summation, adaptation and uncertainty effects, thereby offering a new theoretical interpretation for the vast psychophysical literature on pattern detection. One key component of this model is a task-specific,

normative decoding mechanisms instead of a task-independent maximum-output—or any Minkowski-norm—typically employed in early vision models. This opens the possibility that perceptual learning may at least sometimes be understood in terms of learning the weights of the decoder: Why and when can we successfully learn it, as in the examples presented by Goris et al. (in press)? Why do we fail to learn it in other cases, e.g. Putzeys, Bethge, Wichmann, Wagemans & Goris (PLoS Computational Biology, 2012)? Furthermore, the success of the Goris et al. (2013) model highlights the importance of moving away from ad-hoc models designed to account for data of a single experiment, and instead moving towards more systematic and principled modeling efforts accounting for many different datasets using a single model. Finally, I will briefly show how statistical modeling can complement the mechanistic modeling approach by Goris et al. (2013). Using a Bayesian graphical model approach to contrast discrimination, I show how Bayesian inference allows to estimate the posterior distribution of the parameters of such a model. The posterior distribution provides diagnostics of the model that help drawing meaningful conclusions from a model and its parameters.

- **Task-Specific Optimal Encoding and Decoding**
  W Geisler, J Burge, A D'Antona, J S Perry (Center for Perceptual Systems, University of Texas, Austin, TX, United States)

The visual system of an organism is likely to be well-matched to the specific tasks that the organism performs. Thus, for any natural task of interest, it is often valuable to consider how to perform the task optimally, given the statistical properties of the natural signals and the relevant biological constraints. Such a 'natural systems analysis' can provide a deep computational understanding of the natural task, as well as principled hypotheses for perceptual mechanisms that can be tested in behavioral and/or neurophysiological experiments. To illustrate this approach, I will briefly summarize the key concepts of Bayesian ideal observer theory for estimation tasks, and then show how those concepts can be applied to the tasks of binocular-disparity (depth) estimation and occluded-point estimation in natural scenes. In the case of disparity estimation, the analysis shows that many properties of neurons in early visual cortex, as well as properties of human disparity discrimination performance, follow directly from first principles; i.e., from optimally exploiting the statistical properties of the natural signals, given the biological constraints imposed by the optics and geometry of the eyes. In the case of occluded-point estimation, the analysis shows that almost all the relevant image information is contained in the immediate neighborhood of the occluded point, and that optimal performance requires encoding and decoding absolute intensities; the pattern of relative intensities (the contrast image) is not sufficient for optimal performance. Psychophysical measurements show that human estimation accuracy is sub-optimal, but that humans closely match an ideal observer that uses only the relative intensities. I conclude that analysis of optimal encoding and decoding in specific natural tasks is a powerful approach for investigating the mechanisms of visual perception in humans and other organisms.

- **Modeling common-sense scene understanding with probabilistic programs**
  J Tenenbaum (Massachusetts Institute of Technology, Cambridge, MA, United States)

To see is, famously, to "know what is where by looking". Yet to see is also to know what will happen, what can be done, and what is being done – to detect not only objects and their locations, but the physical dynamics governing how objects in the scene interact with each other and how agents can act on them, and the psychological dynamics governing how intentional agents in the scene interact with these objects and each other to achieve their goals. I will talk about recent efforts to capture these core aspects of human common-sense scene understanding in computational models that can be compared with the judgments of both adults and young children in precise quantitative experiments, and used for building more human-like machine vision systems. These models of intuitive physics and intuitive psychology take the form of "probabilistic programs": probabilistic generative models defined not over graphs, as in many current machine learning and vision models, but over programs whose execution traces describe the causal processes giving rise to the behavior of physical objects and intentional agents. Common-sense physical and psychological scene understanding can then be characterized as approximate Bayesian inference over these probabilistic programs. Specifically, we embed several standard algorithms – programs for fast approximate graphics rendering from 3D scene descriptions, fast approximate physical simulation of rigid body dynamics, and optimal control of rational agents (including state estimation and motion planning) – inside a Monte Carlo inference framework, which is capable of inferring inputs to these programs from observed partial outputs. We show that this approach is able to solve a wide range of problems including inferring scene structure

from images, predicting physical dynamics and inferring latent physical attributes from static images or short movies, and reasoning about the goals and beliefs of agents from observations of short action traces. We compare these solutions quantitatively with human judgments, and with the predictions of a range of alternative models. How these models might be implemented in neural circuits remains an important and challenging open question. Time permitting, I will speculate briefly on how it might be addressed. This talk will cover joint work with Peter Battaglia, Jess Hamrick, Chris Baker, Tomer Ullman, Tobi Gerstenberg, Kevin Smith, Ed Vul, Eyal Decther, Vikash Mansinghka, Tejas Kulkarni, and Tao Gao.

- **Neural theory for the visual recognition of goal-directed actions**
  M Giese[1], F Fleischer[1], V Caggiano[2], J Pomper[3], P Thier[3] ([1]Section for Computational Sensomotorics, University Tübingen; Dept. for Cognitive Neurology, HIH and CIN, University Clinic Tübingen, Germany; [2]Dept. for Cognitive Neurology, HIH and CIN, University Clinic Tübingen; McGovern Institute for Brain Research, M.I.T., Cambridge, MA, United States; [3]Dept. for Cognitive Neurology, HIH and CIN, University Clinic Tübingen, Germany)

The visual recognition of biological movements and actions is a centrally important visual function, involving complex computational processes that link neural representations for action perception and execution. This fact has made this topic highly attractive for researchers in cognitive neuroscience, and a broad spectrum of partially highly speculative theories have been proposed about the computational processes that might underlie action vision in primate cortex. Additional work has associated underlying principles with a wide range of other brain functions, such as social cognition, emotions, or the interpretation of causal events. In spite of this very active discussion about hypothetical computational and conceptual theories, our detailed knowledge about the underlying neural processes is quite limited, and a broad spectrum of critical experiments that narrow down the relevant computational key steps remain yet to be done. We will present a physiologically-inspired neural theory for the processing of goal-directed actions, which provides a unifying account for existing neurophysiological results on the visual recognition of hand actions in monkey cortex. At the same time, we will present new experimental results from the Tübingen group. These experiments were partly motivated by testing aspects of the proposed neural theory. Partly they confirm aspects of this theory, and partly they point to substantial limitations, helping to develop more comprehensive neural accounts for the computational processes that underlie visual action recognition in primate cortex. Importantly, our model accounts for many basic properties of cortical action-selective neurons by simple physiologically plausible mechanisms that are known from visual shape and motion processing, without necessitating a central computational role of motor representations. We demonstrate that the same model also provides an account for experiments on the visual perception of causality, suggesting that simple forms of causality perception might be a side effect of computational processes that mainly subserve the recognition of goal-directed actions.
[Supported by the DFG, BMBF, and EU FP7 projects TANGO, AMARSI, and ABC.]

TALKS : BRIGHTNESS, LIGHTNESS AND CONTRAST

- **Colour and brightness encoded in a common L- and M-cone pathway?**
  A Stockman, D Petrova, B Henning (Institute of Ophthalmology, University College London, United Kingdom; e-mail: a.stockman@ucl.ac.uk)

Flickering lights near 560 nm appear brighter than steady lights of the same mean intensity, whereas lights near 520 or 650 nm appear yellower. Both effects are consistent with the distortion of the representation of the input signal within the visual pathway: brightness enhancement at an expansive nonlinearity and the hue change at a compressive one. We have manipulated the distortion products produced by each nonlinearity to extract the temporal properties of the early (pre-nonlinearity) and late (post-nonlinearity) stages of the L- and M-cone pathways signalling brightness or colour. We find that the attenuation characteristics of both pathways are virtually identical both before and after the nonlinearity: the early temporal stage acts like a band-pass filter peaking at 10-15 Hz, while the late stage acts like a two-stage low-pass filter with a cut-off frequency near 3 Hz. We propose a physiologically-relevant model that accounts for the early and the late filter shapes and incorporates both types of nonlinearity within a common pathway. Modelling suggests that brightness enhancement is caused by rectification whereas the hue change is caused by a smoothly compressive nonlinearity. Plausible sites for the nonlinearities are after subtractive centre-surround antagonism possibly from horizontal cells.

◆ **Do illusory figures have a surface color**

S Zdravkovic[1], Ž Milojevic[2] ([1]Department of Psychology, University of Novi Sad, Serbia; [2]Laboratory for Experimental Psychology, University of Novi Sad, Serbia; e-mail: szdravko@f.bg.ac.rs)

Kanizsa figures, though only partially outlined, tend to stand out from the background with a surface that even appears to be shaded in a different color. Do the properties of this illusory surface behave in the same way as the properties of real surfaces? Here we used simultaneous lightness contrast (SLC) to explore this question. SLC is a visual illusion in which black and white backgrounds modulate the surface color of targets. We replaced SLC backgrounds with inducers (pacmen) that created illusory targets (gray squares) and contrasted this to regular SLC display. The shape and outline-length of the inducers, as well as shades of the targets, were manipulated in three experiments. Participants made lightness matches using a Munsell scale. The SLC effect was just as strong with illusory targets as with real targets. All other relevant aspects of SLC were also observed: the targets on the dark side of SLC were perceived as lighter, the illusion became stronger when darker targets were used and SLC increased with articulation. These results suggest that illusory figures do have an illusory surface and the color of this surface appears to be treated in the same manner as real surface color.

◆ **Why are lightness values compressed in abnormal illumination?**

A L Gilchrist, S Ivory (Psychology, Rutgers University, NJ, United States; e-mail: alan@psychology.rutgers.edu)

Failures of lightness constancy always take the form of gamut compression. To exploit this important clue, we measured the compression for a row of 5 target squares standing in a spotlight (30 X ambient) within a checkerboard-covered vision tunnel. Varying the luminance range of the 5 squares and the checkerboard walls produced 6 conditions that we used to test 5 stimulus metrics potentially underlying the compression. The amount of compression was predicted by the ratio of highest target luminance to highest checkerboard luminance (equivalent to the perceived illumination difference), but not by overall luminance range or by the formula in anchoring theory or by two other metrics. Compression was identical for a row of squares suspended in midair within the tunnel or seen through an aperture on the far wall, showing that border ownership at the boundary enclosing the squares is not critical. However, substantially more compression was produced when the row was placed within a rectangular beam of light projected onto the far wall. This suggests that an occlusion boundary segregates frameworks better than a cast illumination boundary, even though the cast illumination edge reveals the illumination difference between squares and tunnel.

◆ **Predicting lightness judgments from luminance distributions of matte and glossy virtual objects**

M Toscani, M Valsecchi, M D Dilger, A Zirbes, K R Gegenfurtner (Abteilung Allgemeine Psychologie, Justus-Liebig Universität Giessen, Germany; e-mail: matteo.toscani@psychol.uni-giessen.de)

Humans are able to estimate the reflective properties of a surface (albedo) of an object despite the large variability in the reflected light due to shading. We investigated which statistics of the luminance distribution of matte and glossy three-dimensional virtual objects are used to estimate albedo. Seven naive observers were asked to sort six objects in an achromatic virtual scene in terms of their albedo. The objects were uniformly spaced on a horizontal plane under a directional diffuse illuminant. Six different reflectances have been chosen for the objects to allow better than chance, but not perfect discrimination performance. The position of the objects in the scene and their reflectances were balanced over trials. Observers were significantly better in ranking matte objects (50% correct) than glossy ones (33% correct). The physical ranking of matte objects was best predicted by the maximum of the luminance distribution whereas the best predictor for the glossy objects was the mean of the distribution. Observers seemed to exploit these optimal cues: their rankings were mainly based on the maximum and the mean of the luminance distributions for the matte objects and dominated by the mean for the glossy ones.

◆ **Perceptual tests of a cortical edge integration theory of lightness computation using haploscopic presentation**

M Rudd (Howard Hughes Medical Institute, University of Washington, WA, United States; e-mail: mrudd@uw.edu)

Edge integration—the theory that lightness is computed by a cortical process that sums signed steps in log luminance across space—accounts with great precision for lightness judgments obtained with

disk-annuli, Gilchrist dome, and staircase-Gelb displays (Rudd, 2010, submitted). The theory breaks with alternative lightness theories by predicting contrast effects for incremental targets, which violate the highest luminance anchoring principle (Gilchrist et al., 1999; Rudd & Zemach, 2005). Here I test the very strong prediction of cortical edge integration theory that the magnitude of such contrast effects for incremental targets will increase with haploscopic presentation: that is, when targets are presented to one eye and backgrounds having the same luminance and outer dimensions as the annular surrounds used in classical lightness induction studies are presented to the other eye. Haploscopic presentation increases the effect size dramatically, contradicting both the highest luminance principle and any theory that attempts to explain lightness based of image luminances per se, as opposed to edge-based cortical computations. The computations required by the model might be carried out in visual cortex by first encoding luminance edges in V1 and V2, then spatially integrating these edge responses at a later stage, e.g. V4 (Rudd, 2010, ECVP 2011).

- **Linking appearance to neural activity through the study of the perception of lightness in naturalistic contexts**

  M Maertens[1], R Shapley[2] ([1]Modelling of Cognitive Processes, Technische Universität Berlin, Germany; [2]Center for Neural Science, New York University, NY, United States; e-mail: marianne.maertens@tu-berlin.de)

We address the classical question how a psychological experience, in this case apparent lightness, is linked by intervening neural processing to physical variables. We address two issues: how does one know the appropriate physical variable to look at, and how can behavioral measurements be used to probe the internal transformation that leads to psychological experience. We measured lightness transfer functions (LTFs), that is the functions that map retinal luminance to perceived lightness for naturalistic checkerboard stimuli. The LTFs were measured for different illumination situations: plain view, a cast shadow, and an intervening transparent medium. Observers adjusted the luminance of a comparison patch such that it had the same lightness as the test patches. When the data were plotted in luminance-luminance space, we found qualitative differences between mapping functions in different contexts. These differences were greatly diminished when the data were plotted in terms of contrast for which the data were compatible with a single linear generative model. This result indicates that, for the naturalistic scenes used here, lightness perception depends mostly on local contrast. We further discuss that, one may find it useful to consider also the variability of observers adjustments in order to infer the true luminance-to-lightness mapping function.

- **Understanding disability glare: light scatter and retinal illuminance as predictors of sensitivity to contrast**

  E Patterson, G Bargary, J L Barbur (Applied Vision Research Centre, City University London, United Kingdom; e-mail: emily.patterson.1@city.ac.uk)

Forward light scatter within the eye causes a reduction in retinal image contrast, which can be debilitating in the presence of bright light sources. The concurrent increase in retinal illuminance can, however, improve retinal sensitivity under some conditions. The combined effect of reduced image contrast and increased retinal sensitivity remains poorly understood. The effects of glare-source intensity, surround luminance and test target location on the retina are investigated. The aim is to provide a new, more accurate model of contrast sensitivity in the presence of glare. A psychophysical flicker-cancellation test (M. L. Hennelly et al., 1997, Ophthalmic & Physiological Optics, 17, 171) was used to measure the amount and angular distribution of scattered light in the eye. Contrast thresholds were measured using the 'Functional Contrast Sensitivity' (FCS) test (C. M. Chisholm et al., 2003, Aviat. Space Environ. Med., 74, 551-559). Pupil plane, glare-source illuminances (0, 1.35 and 19.21 lm/m^2), eccentricities (5°, 10° and 15°), and background luminance levels (1, 2.6 and 26 cd/m^2) were investigated. In general, predictions based solely on scattered light overestimate the detrimental effect of glare on visual performance. Prediction accuracy is, however, improved significantly by incorporating into the model changes in retinal sensitivity.

- **A study of mechanisms for discomfort glare**

  Y Jia, G Bargary, J L Barbur (Applied Vision Research Centre, City University London, United Kingdom; e-mail: yingxin.jia.1@city.ac.uk)

The presence of a bright light source in the visual field can generate visual discomfort, often described as 'discomfort glare'. The mechanisms underlying discomfort glare remain poorly understood, even after 50 years of multidisciplinary research [Mainster et al., 2012, American Journal of Ophthalmology, 153(4),

587-593]. However, any mechanistic account of discomfort glare must begin with a given quantity of light reaching the retina, and yet previous studies have focused mostly on properties of the glare-source. In this study, the pupil size was measured throughout, while glare-source size, eccentricity and background luminance were varied. The participants were required to view a source of light presented against a simulated residential street background in the form of uniform flashes of light of varying intensity. Discomfort glare thresholds were estimated using a staircase procedure; the dependent variable was retinal illuminance, a quantity proportional to the amount of light per unit area of the retina. It was found that at the threshold for discomfort glare, retinal illuminance is approximately constant and independent of glare-source size, background luminance and eccentricity. A model based on saturation of photoreceptor signals in the retina that accounts for both the glare thresholds and the corresponding pupil responses will be described.

TALKS : ATTENTION

- **The influence of salience-driven and goal-driven influences in overt visual selection**
  M Donk (Dept. of Cognitive Psychology, Vrije Universiteit Amsterdam, Netherlands; e-mail: w.donk@vu.nl)

Overt visual selection can be affected by the relative salience of individual objects in the visual field and by goal-driven influences. The present contribution aims to provide an overview of research performed in our lab showing (a) a major role of salience in early oculomotor selection and (b) a dominant role of goal-driven influences later on. These results suggest that the salience representation is present rapidly after the presentation of a display but vanishes with passing time. After some time, the representation may only include information about where salient objects are in a background, lacking all information concerning how salient those objects are. Salience in this sense might be perceived as a wheelbarrow to segregate objects from the background, providing the basis for subsequent goal-driven selection.

- **Practice Strengthens Spatiotopic, and Weakens Retinotopic, Inhibition of Return**
  H Krueger, A Hunt (Psychology, University of Aberdeen, United Kingdom; e-mail: hannah.krueger@gmail.com)

The ability to search the visual environment is a crucial function of the visual system. The finding that a cued location is inhibited if attention has been removed from this location is one potential mechanism to facilitate efficient search. Inhibition of Return (IOR) is known to be coded in space-based coordinates, consistent with the idea that IOR facilitates search. However, recently studies have emerged that report retinotopic inhibition alongside the spatiotopic tag, casting doubt on the putative function of IOR. We examined IOR over extended task exposure, measuring reaction time to detect a target in cued and uncued locations with a saccade intervening between the cue and target. Retinotopic IOR was weakened with practice , and eliminated in the final third of the experiment. Spatiotopic IOR, in contrast, was strengthened by practice. This finding is consistent with retinotopic IOR being an undesirable, but avoidable, consequence of inhibiting locations while moving the eyes. Unfamiliar laboratory tasks may produce retinotopic IOR that would perhaps not be observed in more naturalistic or familiar search situations. Studies examining the remapping of spatial attention should take practice effects into account.

- **Pupil dilation deconvolution reveals the dynamics of attention at high temporal resolution.**
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The size of the human pupil increases in response to meaningful stimuli and cognitive processing. However, this response is slow and its use is therefore thought to be limited to measurements of tasks in which meaningful events are temporally well separated. Here, we show that high temporal information on attention and cognitive processes can be obtained from the slow response of the pupil. Using automated dilation deconvolution, we isolated and tracked the dynamics of attention in a fast-paced attentional blink task, allowing us to uncover the amount of mental activity that is critical for conscious perception of relevant stimuli. We thus found evidence for specific temporal expectancy effects in attention that have eluded detection using neuroimaging methods such as EEG. In addition, we present direct evidence for the crucial role of the processing demands of the first target, and we show that unreported targets do elicit a distinct cognitive response. Combining this approach with other neuroimaging techniques can open many research opportunities to study the temporal dynamics of the mind's inner eye in great detail.

- **Left visual-field advantage for detecting learned targets in rapid serial visual presentation**
  A Karas, C Kaernbach (Institut für Psychologie, Christian-Albrechts-Universität zu Kiel, Germany; e-mail: chris2013@kaernbach.de)

Rapid serial visual presentation (RSVP) has often been used to study conscious and unconscious processing of fast visual input. Dual-target paradigms with a first (T1) and a second (T2) target model the ecologically valid situation that we are searching the visual world for more than one type of relevant targets. In dual-stream studies it has been found that T2 in the left visual field have a much better chance to be consciously perceived. This left visual-field advantage (LVFA) seems to be due to an advantage of the right hemisphere to direct attention to relevant external stimuli. Studies of the LVFA have to be careful about the stimuli as there are hemispheric asymmetries concerning the processing of certain stimulus types (letters, digits, faces). In previous studies the targets were selected from a different set of stimuli than the distractors in order to make them pop out from the distractor stream. This complicates interpretation of the found asymmetries. The present study presents for the first time a LVFA for targets that were taken from the same stimulus set as the distractors and that differed from the distractor set only by instruction and training.

- **Bilateral field advantage in subitizing: Visual object selection is restricted to single items in each visual hemifield**
  H Railo (Department of Psychology, University of Turku, Finland; e-mail: hmrail@utu.fi)

Earlier studies suggest that object-based attention can only select one item at a time [Duncan, 1984, J Exp Psy: Gen, 113, 501-517], but participants can nevertheless individuate and access multiple objects simultaneously [Cavanagh & Alvarez, 2005, Psych Sci, 16, 637-643]. Such object individuation capacity has been shown to be split between hemifields. If the left and right visual hemifields have independent object individuation capacities, it should be reflected in subitizing, which refers to the effortless and errorless apprehension of small numbers of items (1–3). The present study shows that subitizing is faster and more accurate when items are presented bilaterally than unilaterally. Visual crowding cannot explain the results. In fact, the participants could report the number of two objects faster than the number of a single object, but only when the two objects were presented bilaterally. This speaks against both classical serial and parallel models of visual selection, and can be best explained by assuming independent attentional selection for the hemifields. The results support the view that the visual system can simultaneously select only one item per hemifield. The speed of subitizing is explained by object-based attentional selection, but the capacity of subitizing is explained by visual short-term memory.

- **Diverting attention impairs or improves performance by decreasing spatial resolution**
  A Barbot, L A Bustamante, M Carrasco (Department of Psychology & CNS, New York University, NY, United States; e-mail: antoine.barbot@nyu.edu)

Spatial resolution peaks at the fovea and declines with eccentricity. Heightened resolution is often useful but can be detrimental. For instance, in texture segmentation tasks constrained by resolution, performance peaks at mid-periphery, where resolution is optimal for the texture scale, and drops where resolution is either too low (periphery) or too high (central locations). Exogenous (involuntary) attention increases resolution at the attended area, improving performance at peripheral locations but impairing performance at central locations. Here, we investigated how exogenous attention affects performance at unattended areas. Observers detected or discriminated the shape of a texture patch embedded in a texture display, which appeared at several eccentricities. Exogenous attention was manipulated using uninformative peripheral precues. The locations of the precue and response cue matched (valid) or did not (invalid). Consistent with previous studies, performance in the neutral (distributed) attention condition peaked at mid-periphery and valid precues increased resolution, impairing and improving performance at central and peripheral locations, respectively. Conversely, with invalid precues, performance decreased at peripheral locations but improved at central locations, where increasing resolution hinders performance. Our findings reveal that, counterintuitively, diverting attention can improve performance by decreasing resolution, consistent with exogenous attention being an inflexible mechanism that trades-off spatial resolution.

- **Object identity changes and the target blanking effect**
  J MacInnes, A Hunt (Psychology, University of Aberdeen, United Kingdom; e-mail: j.macinnes@abdn.ac.uk)

Visual input is a series of stable fixations separated by saccades, but perception is continuous. It has been proposed that visual stability is maintained, in part, by a series of presaccadic predictions followed by postsaccadic confirmations (or disconfirmations). Indeed, detection of trans-saccadic object displacements can be improved by introducing temporal disruptions to the object. This target blanking effect could be caused by a failure in the prediction of object location and/or identity across a saccade that facilitates comparison of pre- and post-saccadic location information. If so, successful detection of object displacements might be a useful indicator of a mismatch in the predicted vs. actual post-saccadic perception. We explore this idea using images of real-world objects and a variety of changes in object features and identity. We replicate the target blanking effect and show that small changes in object features, such as colour, do not influence displacement detection. However, changes from one object type to another interferes with displacement discrimination and blocks the target blanking effect, contrary to the hypothesis that the latter effect is driven by discontinuity in object perception. The results suggest temporal gaps and trans-saccadic object identity changes influence visual stability in different ways.

- **Noise modulates the magnitude of the attentional blink in natural scenes**
  O Hansen-Goos, S Marx, W Einhauser (Neurophysics, Philipps-University Marburg, Germany; e-mail: wet@physik.uni-marburg.de)

The attentional blink (AB) occurs when items are presented in rapid sequence (rapid serial visual presentation – RSVP). When a second target (T2) follows another (T1) within a short interval, processing of T2 is impaired. To test the effect of noise on the AB, we presented RSVP sequences of natural scenes, which each contained 0, 1 or 2 animal targets. Observers reported target number and category (avian, canine, feline, pachydermatous). In some sequences, noise was added to the phase of all images' Fourier spectrum. Even for noise-levels that did not interfere with detection or categorization in single-target trials, we found profound effects on the AB: the AB's magnitude at lag-1 increased with noise, while at lag-2 detection was indistinguishable from single-target baseline. For both lags, the influence of T2 on T1 was equal to the typical AB (T1 on T2). Categorization errors increased with phase noise, but remained mainly between categories sharing similar features. We conclude that "lag-1 sparing", the absence of an AB if T2 follows T1 immediately, is not a generic property of the AB, but modulated by noise-induced processing load. Our results highlight the difference between complex stimuli and those artificial items, which AB experiments typically use.

TALKS : CLINICAL VISION

- **Retinotopy of the cortical lesion projection zone in macular degeneration**
  F Cornelissen[1], K Haak[2], A B Morland[3] ([1]University Medical Center Groningen, Netherlands; [2]Psychology, University of Minnesota, MN, United States; [3]Department of Psychology, University of York, United Kingdom; e-mail: f.w.cornelissen@umcg.nl)

Macular degeneration (MD) causes lesions to the center of the retina. There is no cure for MD but several promising treatments aim at restoring retinal lesions. These treatments assume that the patient's brain can still process the retinal signals once they are restored, but whether this is correct has yet to be determined. In previous work, we established that long-term visual deprivation does not result in cortical remapping, while it does lead to cortical degeneration. Here, we used functional magnetic resonance imaging (fMRI) and a new data-analysis tool – connective field modeling – to evaluate retinotopy in the cortical lesion projection zone (LPZ). We found that connectivity between the LPZ in areas V1 and V2 is still retinotopically organized in MD, although less so than in controls with simulated retinal lesions. Moreover, the decreased connectivity in MD correlated strongly with fixation instability, but not with retinal lesion size. This suggests that the difference between MD patients and controls may be related to poor fixation and that the retinotopy of the LPZ remains largely intact, despite the prolonged loss of visual input. These results suggest that the restoration of sight in MD can probably assume largely unchanged cortical visual fields maps.

- **Reduction of frontal white matter volume in patients with age-related macular degeneration**
  D Prins[1], A T Hernowo[1], H A Baseler[2], T Plank[3], A D Gouws[4], J M Hooymans[1], A B Morland[2], M W Greenlee[3], F Cornelissen[1] ([1]Laboratory for Experimental Ophthalmology, University Medical Centre Groningen, Netherlands; [2]Department of Psychology, University of York, United Kingdom; [3]Institute for Experimental Psychology, University of Regensburg, Germany; [4]Centre for Neuroscience, Hull-York Medical School, United Kingdom; e-mail: d.prins@umcg.nl)

Macular degeneration (MD) causes central visual field loss. When field defects occur in both eyes and overlap, parts of the visual pathways are no longer stimulated. Previous reports from our group have shown that this is associated with volumetric changes in the grey and white matter of the visual pathways [Hernowo et al., 2013, Cortex, in press]. Here investigate whether MD is also associated with volumetric changes outside the visual pathways. In this multicentre study, we included 113 subjects: 58 subjects with MD – juvenile MD (JMD) as well as age-related MD (AMD) – and 55 healthy controls. We used high-resolution anatomical magnetic resonance imaging and voxel-based morphometry to investigate whether there were any volumetric changes in grey and white matter between patients and controls. In addition to grey and white matter reductions in the visual pathway, AMD patients (but not JMD patients) showed volumetric changes beyond the visual pathways. Particularly the frontal white matter volume is decreased in AMD patients. Our results implicate that loss of retinal sensitivity in AMD is associated with degeneration of white matter in the frontal lobe. This reduction in frontal white matter volume – only present in the AMD patients – may constitute a neural correlate of a previously reported association between AMD and mild cognitive impairment.

- **A role of the human thalamus in predicting the perceptual consequences of eye movements**
  F Ostendorf, D Liebermann, C Ploner (Department of Neurology, Charité - Universitätsmedizin Berlin, Germany; e-mail: florian.ostendorf@charite.de)

Internal monitoring of oculomotor commands may help to anticipate and keep track of changes in perceptual input imposed by our eye movements. Neurophysiological studies in non-human primates identified corollary discharge signals of oculomotor commands that are conveyed via thalamus to frontal cortices. We tested whether disruption of these monitoring pathways on the thalamic level impairs the perceptual matching of visual input before and after an eye movement in human subjects. Fourteen patients with focal thalamic stroke and twenty healthy control subjects performed a task requiring a perceptual judgment across eye movements. Subjects reported the apparent displacement of a target cue that jumped unpredictably in sync with a saccadic eye movement. In a critical condition of this task, six patients exhibited clearly asymmetric perceptual performance for rightward versus leftward saccade direction. Furthermore, perceptual judgments in seven patients systematically depended on oculomotor targeting errors, with self-generated targeting errors erroneously attributed to external stimulus jumps. Voxel-based lesion-symptom mapping identified an area in right central thalamus as critical for the perceptual matching of visual space across eye movements. Our findings suggest that trans-thalamic corollary discharge transmission decisively contributes to a correct prediction of the perceptual consequences of oculomotor actions.

- **Home-based training for individuals with homonymous visual field defects**
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Homonymous visual field defects (HVFDs) are a common consequence of stroke. Effective compensatory therapies have been developed which train individuals to adopt more efficient strategies for visual exploration. However, this training is typically undertaken in clinical settings or at home under expert supervision. The scale of the resources needed for these interventions limits their potential as an affordable tool for neurorehabilitation. To address this issue we developed and evaluated an unsupervised, home-based computer training for individuals with HVFDs. Seventy individuals with chronic HVFDs were randomly assigned to one of two groups: combined reading and exploration training or attention training. Visual and attentional abilities were assessed before and after training using perimetry, visual search, reading, activities of daily living, the Test of Everyday Attention, and a Sustained Attention to Response task. The combined reading and exploration training group experienced significant objective

and subjective improvements in visual exploration and reading. The benefits of the exploration and reading training were significantly greater than those of the control intervention. We conclude that home-based compensatory training is an inexpensive accessible rehabilitation option for individuals with HVFDs, which can result in objective benefits in searching and reading, as well as improving quality of life.

- **The neuropsychology of Gestalts, from case studies to screening tests: patient DF, and the Leuven Perceptual Organization Screening Test**
  L De-Wit[1], K Vancleef[1], K Torfs[2], J Kubilius[3], H P Op de Beeck[3], J Wagemans[1] ([1]Laboratory of Experimental Psychology, University of Leuven (KU Leuven), Belgium; [2]Institute of Neuroscience, University of Louvain, Belgium; [3]Laboratory of Biological Psychology, University of Leuven (KU Leuven), Belgium; e-mail: lee.dewit@psy.kuleuven.be)

The patient DF has predominately been studied in terms of a dissociation between relatively preserved vision for action, and a profound disruption to vision for perception. This talk will focus just on DF's residual vision for perception, and highlight how this patient's visual form-agnosia impairs the construction of surfaces and the ability to guide attention within objects. Indeed we will demonstrate that configural information that normally offers a huge advantage to healthy observers actually places a large cost on DF's search performance. These studies offer some important insights into the underlying mechanisms responsible for constructing Gestalts. These insights are however significantly limited when restricted to the results of one patient, with a necessarily idiosyncratic lesion. For this reason we have developed the L-POST, or Leuven Perceptual Organization Screening Test, which consists of 15 sub-tests to assess a range of Gestalt and mid-level phenomena. The test is implemented online, is free to use, has a norming sample of over 1200, and has been validated with over 40 patients. The test allows clinicians to screen for deficits in visual perception, and enables researchers to get a broader overview of the Gestalt and mid-level processes that are preserved or disrupted in a given patient.

- **Dissociation between size constancy for perception and action in a patient with bilateral occipital lesions**
  I Sperandio[1], R Whitwell[2], P A Chouinard[2], M A Goodale[2] ([1]School of Psychology, University of East Anglia, United Kingdom; [2]The Brain and Mind Institute, University of Western Ontario, ON, Canada; e-mail: i.sperandio@uea.ac.uk)

Our visual system shows size constancy: an object is perceived as being the same size even though its image on the retina varies continuously with viewing distance. A recent fMRI study [Sperandio, Chouinard and Goodale, Nature Neuroscience, 15, 540-542] demonstrated that activity in the primary visual cortex (V1) reflects size constancy. But is V1 always critical for size constancy? To answer this question, we carried out a size constancy study on patient M.C., who has large bilateral occipital lesions that include V1. We first measured M.C.'s ability to estimate the perceived size of objects of different physical sizes positioned at varying distances. M.C.'s estimates were poorly scaled to the physical size of the objects and were correlated instead with their retinal image size, showing no evidence of perceptual size constancy. In contrast, when we asked M.C. to reach out and pick up objects positioned at different distances, her grip aperture scaled to the real width of the target regardless of viewing distances. Our findings strongly suggest that the neural mechanisms underlying size constancy for perception and action are distinct, and lend further support to the notion that V1 might play an important role in conscious visual perception.

- **Visual masking deficits in healthy and schizophrenic women**
  A Brand[1], E Chkonia[2], M Roinishvili[3], M Herzog[4] ([1]Institute of Psychology and Cognition Research, University of Bremen, Germany; [2]Department of Psychiatry, Tbilisi State Medical University, Georgia; [3]Vision Research Laboratory, I. Beritashvili Center of Experimental Biomedicine, GA, Georgia; [4]Laboratory of Psychophysics, École Polytechnique Fédérale de Lausanne, Switzerland; e-mail: abrand@uni-bremen.de)

Schizophrenic patients have serious visual masking deficits which are likely related to the genetic underpinnings of the disease because also unaffected relatives of the patients show masking deficits. We presented a left/right offset vernier followed by an ISI and a masking grating. Observers indicated the offset direction. We determined the SOA (vernier duration plus ISI), to reach 75% correct responses. Analyzing a new sample, we found that patients (n=239) needed SOAs of 127.6ms, relatives (n=125) of 62.4ms, and controls (n=145) of 32.2ms. In addition, we analyzed the data for the groups separately for men and women. We found main effects of Group and Gender but no significant interaction. Female

observers needed SOAs of about 15ms longer than the male observers in the control group, 25ms in the relatives group and 37ms in the schizophrenia group. For the control group, hence, females performed by a factor of nearly 2 worse than males. No gender effect was found for executive functions as measured with the WCST. It seems that both gender and the susceptibility for schizophrenia are independent main effects affecting spatio-temporal vision. Our results show that a proper gender balance is crucial in experiments where signal to noise ratio is low.

◆ **State of the Freiburg Visual Acuity Test – Dangers and Possibilities**
M Bach[1], A Daub[2] ([1]Eye Hospital, University of Freiburg, Germany; [2]Institute of Biology, University of Freiburg, Germany; e-mail: michael.bach@uni-freiburg.de)

The Freiburg Visual Acuity Test (FrACT) is an automated vision test, implemented as a multi-platform computer program. Various optotypes (Landolt-C, Tumbling E, Sloan letters, faces and hyperacuity Verniers) can be presented. The optotype's size is controlled by a modified Best PEST adaptive staircase procedure, estimating visual acuity. Another branch of FrACT assesses contrast vision. FrACT can be used on-line or downloaded freely. For 20+ years FrACT has been independently validated and applied in numerous laboratories. Major recent changes were (1) additional tests and settings on request, and (2) safeguards against misuse. FrACT cannot replace understanding the fundamentals of acuity assessment: In a highly cited study, FrACT was exploited incorrectly, with wrong conclusions on visual acuity in autism. We recently assessed the optimal number of trials in a sizable sample. We compared 2x100 acuity conditions (normal and blurred vision) in 26 subjects and calculated repeatability measures for 6, 12, 18, 24, ... 48 trials. Result: Test-retest variability declines steeply from 6 to 18 trials, for more trials there is no further significant decline. The product of test time with variability displays a local minimum at 18 trials. Thus, appropriately applied, FrACT can screen acuity quite efficiently.

POSTERS : ILLUSIONS

◆ **Taking Aim in the Plane**

1 A van Doorn, J Koenderink, J Wagemans (Laboratory of Experimental Psychology, University of Leuven (KU Leuven), Belgium; e-mail: andrea.vandoorn@telfort.nl)

In an experiment on 3D pictorial space we encountered an unexpected systematic error regarding the directions in the frontoparallel plane. To investigate the effect we devoted a special study to the same phenomenon in the purely 2D visual field. Observers view a large field filled with a uniform background texture, looking evidently frontoparallel. We superimpose a target and a pointer on this background, both presented at random locations. Thus both the mutual distance and direction are random.The task is to simply aim the pointer at the target for about a thousand target-pointer combinations. We find that observers commit both random and systematic errors, the latter dominating and amounting to as much as ten degrees. The systematic errors occur in a well defined pattern, which is the same for all observers. The deviations vanish for the vertical, the horizontal, and the diagonal directions. The settings deviate from the veridical away from the vertical and horizontal. Perhaps surprisingly, the mutual distance of target and pointer has only a minor influence. We relate this pattern to observations of orientation judgments and discriminations made through the nineteenth and twentieth century.

◆ **Testing visual illusions: Evidence from Perception and Mental Imagery**

2 J Blanusa[1], S Markovic[2], S Zdravkovic[3] ([1]Laboratory for Experimental Psychology, University of Belgrade, Serbia; [2]University of Belgrade, Serbia; [3]Department of Psychology, University of Novi Sad, Serbia; e-mail: jelena.blanusa@gmail.com)

This study aimed to investigate the relationship between visual perception and visual mental imagery. Relying on neuroimaging data, that indicated great similarity between the processes, we assumed no difference between perception and imagery. However, results obtained in behavioral studies were not unanimous. Therefore, we used visual illusions to establish relationship between the two processes. We also attended to a number of methodological issues reported in previous behavioral studies. Participants were asked to estimate the size of lines in Vertical-horizontal illusion, either in perceptual or imagery task. Results showed no difference in the illusion size in both tasks. In addition, there was no difference in the absolute size of estimated stimuli or in the variability of results ($F(1,257)=0.59$, $p>0.05$). In the second experiment we introduced additional factor, stimuli size. Results confirmed previous findings but revealed sex differences in the absolute size of mental image. While male subjects performed equally in the two tasks, female subjects tended to underestimate stimuli size in imagery task. This tendency

intensified as the size of stimuli increased ($F(2,404)=8.8$, $p<0.001$). It is seems that, unlike male subjects, female subjects create smaller mental images for imagery than for perception.
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◆ **The effect of the stimulus shape on tilt judgment**

3 T Ueda, T Yasuda, K Shiina (Faculty of Education and Integrated Arts, Waseda Univeristy, Japan; e-mail: uedaman@ruri.waseda.jp)

The Okuma illusion [Yasuda, et al, 2012, Perception, 41(10),1277–1280] is a visual illusion in which the tilt of two objects in an image is perceived differently when the image is rotated. The difference of object shapes, geometric or not above all, would be a primary factor of the illusion. In this study, we tested the effect of the object shapes in a tilt judgment task by measuring the difference threshold of the tilt. Forty-six participants were first required to adjust upright the several geometric or non-geometric figures. Then in a randomized series of presentation, they were asked to judge if a stimulus was shown tilted as fast and accurate as possible. The result of the experiment showed that non-geometric stimuli, which were complex and had less vertical and horizontal components in shape, had a wider difference threshold. The result suggested that the difference of the sensitivity in tilt perception was a cause of the Okuma illusion.

◆ **Outlined and filled distracters in the visual illusions of the Brentano type**

4 A Gutauskas, A Bulatov, N Bulatova (Institute of Biological Systems, Lithuanian University of Health Sciences, Lithuania; e-mail: alggut@vision.kmu.lt)

It is known that early visual processing is accompanied by the effects of contour extraction which occurs due to spatial frequency filtering possessing the properties of 2D second derivative (the Laplacian operator). Therefore, the filtering should strengthen the similarity of excitation profiles evoked by the outlined or filled contextual objects having the same shape, and one can expect that applying of these different distracters in length-matching tasks should cause approximately the same illusory effects. In order to check this prediction, the psychophysical study with stimuli comprising three circular sectors arranged according to ordinary Brentano pattern, has been performed; the radius of the sectors was used as the independent variable. As it was expected, the experiments with different distracters (either the outlined or uniformly filled) yielded similar results, and the shape of the experimental curves can be completely explained by our model of automatic centroid extraction [Bulatov et al, 2009, Acta Neurobiologiae Experimentalis, 69 (4), 504-525].

◆ **Experiments and Computational Models for the Ames Window Illusion**

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Purpose: To examine systematically factors affecting the Ames Window illusion, toward a future study comparing schizophrenia patients and controls; to produce stimuli that span the range from extremely weak to extremely strong illusions; to develop models that predict performance by assigning appropriate weights to the examined factors. Methods: Factors examined: (1) Long-to-Short base ratio "LS", (2) Height-to-Short base ratio "HS", (3) presence of Shadows "SH". These factors were varied systematically to produce nine rotating stimuli; these were used in two experiments to assess illusion strength using two measures: Asking observers to report (A) which side was in front at selected instances; (B) reversals in rotation direction. The data were fed to an algorithm to determine optimal weights. Results: The two measures produced results that agreed closely, thus confirming the validity of the methods. The optimization algorithm yielded weights that produced significant correlations with the experimental data. Conclusions: Illusory strength increased primarily with growing LS ratio, followed by the presence of shadows, then with decreasing HS ratio. The results have set the stage for the next step: testing schizophrenia patients and controls to test for potential differences in the top-down bias for perceiving frontoparallel trapezoids as rectangles slanted in depth.

◆ **Annular Solar Eclipse illusion: Observing the Rosenbach phenomenon in the natural world?**

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The aim of our study is to discuss Annular Solar Eclipse illusion observed in video work (Suzuki, 2013), shot in 20-21 May 2012, which is similar to New Moon Illusion (Sugano, 2007) and to investigate the factor of these illusion. As it appears in Turner's painting Fishermen at Sea, visual artists express the Moon as figure on background of altocumulus cloud as ground. Sugano (2007) pointed out there is the reversal of figure-ground in perception of moon and clouds. Suzuki's video work Annular Solar Eclipse and Clouds showed three types of optical illusions occur, when a moving altocumulus cloud forms at the same time as Eclipse starts. The first occurred when Full Eclipse started. The perception in this case was that two-dimensionality changes to three-dimensionality as the cloud passes Full Eclipse. The second illusion occurred as the altocumulus cloud was actually passing behind rather than in front of Partial Eclipse. The third illusion was that the cloud passed in front of Partial Eclipse: the perception was as if the cloud was actually wrapping around the Eclipse. Our result from observation was consistent with the findings of previous studies on the factor affecting figure-ground perception.

◆ **Center-of-mass alterations in the Oppel-Kundt illusion**

7 A Bulatov, A Gutauskas, N Bulatova, L Mickiene (Institute for Biological Systems and Genetics, Lithuanian University of Health Sciences, Lithuania; e-mail: bulatov@vision.kmu.lt)

In the present communication, the predictions of our computational model of automatic centroid extraction [Bulatov et al., 2009, Acta Neurobiologiae Experimentalis 69(4), 504-525] have been checked by the results of psychophysical study of the Oppel-Kundt illusion. It has been tested in experiments whether the illusion magnitude can be varied by altering the position of additional non-target spots placed in proximity of stimulus terminators: it was expected that such center-of-mass manipulations should affect the neural computation of perceived length and either increase or decrease the illusion magnitude in comparison with that for unaltered form of the Oppel-Kundt figure. A good correspondence between the model predictions and the illusion magnitude changes provides evidence supporting the suggestion that processes of automatic centroid extraction are certainly linked (although do not determine completely) to the emergence of the Oppel-Kundt illusion. It was shown also that the changes of the illusion magnitude obtained in the present study are commensurate with those established in our previous studies of illusions of extent of the Müller-Lyer type.

◆ **Drifting triangles illusion and its enhancement by shaking or blinking**

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We found a new optical illusion in which many longwise isosceles rectangles of the same shape are arranged so that their bases become mutually parallel and they appear to move in the direction of the bases of triangles contained inside them. The triangles look like a shoal of fishes swimming slowly. Various still images can be perceived as moving. Among them, CDIs and PDIs, including the Fraser-Wilcox illusion and Kitaoka's optimized Fraser-Wilcox illusion, have a feature where the direction of motion is decided only by the illusory image. Most such illusory images require at least three gray levels, for example, black, gray, and white. The known exceptions are very rare and are only the drifting arrows and convex-directed motion illusions, both of which were found by Kitaoka [http://www.psy.ritsumei.ac.jp/ akitaoka/CRESTmeeting2012.html]. This new illusion also requires only two gray levels of black and white. In addition, it is quite simple because it consists of black rectangles on a white background and vice versa. Furthermore, the effect of the optical illusion is strengthened when the image is shaken in the direction perpendicular to the direction of illusory motion or by blinking between the original and reversed images at a frequency of several Hz.

◆ **Helmholtz illusion on clothing revisited**

9 H Ashida, K Kuraguchi, K Miyoshi (Graduate School of Letters, Kyoto University, Japan; e-mail: ashida@psy.bun.kyoto-u.ac.jp)

A square filled with horizontal stripes is perceived as thinner and taller than one with vertical stripes (Helmholtz illusion). This is counterintuitive given the common belief that horizontal stripes make us look fatter. Thompson and Mikellidou [2011, i-Perception, 2, 69-76] confirmed the Helmholtz effect, but

the reason for the discrepancy is not fully understood. In this study, we measured the point of subjective equality (PSE) in the perceived body width by pairwise comparison of female figures with horizontal and vertical stripes. The results highlighted three factors that might underlie the discrepancy. First, the Helmholtz effect is more pronounced for a thin figure than for a fat one, with possible reversal for the latter. Second, the PSE was diverse across participants, ranging from positive to negative values for both fat and thin figures. Third, there was a strong effect of block order; whether the participants were tested with a fat or thin figure first, the results in the second block became closer to those in the first block. We conclude that the effect of striped clothing on perceived body shape is essentially complex, depending on many factors such as fitness of the person and surrounding people, and possibly on watchers' attitudes.

◆ **Reversal of the color-dependent Fraser-Wilcox illusion under a dark condition**

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Kitaoka and Ashida (2003, VISION, 15, 261-262) analyzed the Fraser-Wilcox illusion, a pattern-dependent motion illusion which is observed in a stationary image, and separated one elemental illusion from another, which rivaled each other in the original image. Kitaoka and Ashida proposed the "optimized" Fraser-Wilcox illusion, which has a much stronger effect than the original because of cooperation of the two elemental illusions. The optimized illusion depends on a particular luminance profile and its temporal change in appearance is loose or tonic. On the other hand, Kitaoka (2010, Introduction to Visual Illusion, Asakura-shoten, Tokyo) proposed a color-dependent version, which depends on a particular color profile and its temporal change in appearance is abrupt or phasic. Yanaka and Hilano (2011, Perception, 40 ECVP Supplement, 171) revealed that shaking the image enhances the color-dependent illusion. The present study demonstrates a reversal of the direction of motion in the color-dependent illusion when a printed image is weakly illuminated or is observed in the mesopic vision. No reversal occurs in the luminance-dependent one. We discuss the reversal suggesting the role of rods in modulation of perceived brightness and possible involvement of the luminance change-induced motion illusion (Anstis 1970, Vision Research, 10, 1411-1430).

◆ **Neural correlates of local and global characteristics in the Fraser illusion**

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Event-related brain potentials (ERPs) were used to examine the neural correlates of the Fraser illusion [Fraser, 1908; British Journal of Psychology, 1904-1920 (2), 307–320]. The studied Fraser illusion consists of black and white twisted cords on a chromatic patchwork background, where the concentric circles appear as a single spiral. Since the twisted cords (local orientations) and concentric circles (global configuration) contribute differently to the spiral illusion, we designed three additional variants by changing the local orientations, from twisted to parallel cords, and by changing the global configuration, from concentric to spiral circles, separately. Results of behavioral 'concentric' versus 'spiral' judgments in the four conditions showed that the local orientations dominated the illusory appearance. That is, for the displays with twisted cords an illusory appearance was most evident. We compared the ERP grand average waveforms of illusion and non-illusion responses over all conditions. When an illusory percept was reported we found a more positive component between 225-275 ms at the posterior scalp. We discuss the potential influence of local and global features on the neural mechanism of this illusion.

◆ **Decoding sensation and perception over time with EEG pattern cross-classification**

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Visual representations evolve as visual information passes through successive processing stages on the way from the retina to conscious awareness. Using EEG in combination with a visual illusion that allowed us to dissociate veridical and perceived position, we tracked the neural representation of visual position over time. Multivariate pattern classification of single EEG trials showed that the veridical position of a visual stimulus can be decoded from EEG activity very rapidly following stimulus presentation, as would be expected from the known retinotopic organization of early visual areas. However, we show that the illusory, rather than veridical location can also be decoded very rapidly: already around 80 ms after stimulus onset, the classifier is better able to distinguish two stimuli when they are perceived to be far apart than when they are perceived to be close together – even when both

stimulus pairs are in identical positions. Finally, we show that the information coding veridical and perceived position has dissociable neural origins. Using this technique we are able to trace the evolution of neural representations from low-level sensation to higher-order perception over both space and time.

◆ **Turn yourself around as the spinning dancer: Sound modulates the spinning direction of**
13 **the silhouette illusion**

A-Y Chang, S-L Yeh (Department of Psychology, National Taiwan University, Taiwan; e-mail: b96207015@ntu.edu.tw)

In the silhouette illusion, the profile of a female dancer can be perceived as spinning clockwise or counterclockwise. Since a spinning object is often accompanied by a sound change, we examine whether adding a sound track that changes volume consistent with what the dancer would hear were she moving in that direction can alter participant experience of the illusion. We discovered that participants reported more switches in direction of spin with sound than without, and that the perceived spin direction was consistent with the dancer's perspective—what she would hear—rather than with the participant's perspective. Indeed, these findings correlate with participants' aptitude for perspective-taking and empathic concern. This is the first study to demonstrate that dynamic, sensory stimuli affect participants' experience of the illusion in a way that is peripersonal—not for them, but for the dancer. That is they see the rotation in a way consistent with sensory experiences that they attribute to the dancer.

◆ **The Dancing Diamonds Illusion**

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The illusion of movement reported relies on luminance changes and phasing of fills to produce an array of diamonds so dazzling that to the observer they seem to have a life of their own! Furthermore, an interesting figure-ground reversal can be seen in the illusion when adjusting diamond size. However, it is the complexity of movement seen that is of prime interest and which gives the illusion its name. There is an underlying rationale as to why the diamonds appear to dance (Shapiro, et al. 2005. JOV (5)764-82). However, the interactions in the illusion are intriguing and we examined a variety of factors that contribute to this and which may be used to optimise the illusory sense of motion. Amongst these we found that i) the background luminance; ii) luminance of the diamond edges, and iii) diamonds' size, and configuration play a significant role. The illusion also demonstrates some differences between foveal and peripheral vision where apparent motion is influenced by viewing distance. Furthermore, if viewers get close enough to the screen to position the retinal image of a single diamond exactly on their fovea. The diamond does not move whilst the others seen in peripheral vision, continue their dance.

◆ **Pseudo-random pattern image with an embedded hidden message perceived when vibrated**

15 T Hilano, T Kageyama, K Yanaka (Faculty of Information Technology, Kanagawa Institute of Technology, Japan; e-mail: hilano@ic.kanagawa-it.ac.jp)

We report how to make an image with an embedded hidden message, which is perceived when we make the image vibrate. The process consists of three steps: (1) make a black and white bitmap image of a hidden message, (2) create two groups of figures of a fixed size that consists of two types of blocks with a random arrangement that satisfies the given conditions, and (3) create the final image by selecting the image belonging to the group corresponding to the color of each pixel of the bitmap image created at step (1) at random. Thus, the size of the final image is enlarged by the size of the blocks, i.e., the size of the blocks made at step (2) are t times t. Then, the size of the final image is enlarged to t times in both directions. We discuss the conditions in which the hidden message contained in this image is hard to perceive while it stands still and easy to perceive while we make it vibrate. The conditions under consideration are colors, sizes, and the ratio of the blocks mentioned at step (2) and the font that makes the hidden message.

◆ **The Mosaic Illusion on the floor of the Siena Doumo**

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The authors of this paper discovered a new geometrical optical illusion in a chain of mosaics, laid between the 14th and 16th centuries, on the floor of the Duomo in Siena, Italy. Our study shows that these previously unidentified perceptual phenomena exist and result from an unstable background which contributes to this type of geometrical optical illusion. The Gothic style mosaics consist of inlaid pieces which surround the icon often identified as the Imperial Eagle, located at the third composition from the

entrance. These mosaics are composed of successive 'Mach book' figures (see E. Rubin (1921)), defined as two-dimensional shapes which look three-dimensional without a background (see Mach (1883)). The same perceptual phenomenon is also found in the mosaic inlay of what is referred to as the Wheel of Fortune at the fifth composition from the entrance. These mosaics are shaped as parallelograms and consist of white and brown mosaics. Because of the unstable background, these patterns can appear as either a stairway ascending to the right with white steps or as a stairway ascending to the left with alternating brown steps. No previous studies (Mach (1883) among others) have referred to these geometric optical illusions in the Duomo.

◆ **The T-illusion in Variable Contexts**

17 K Landwehr (Allgemeine Experimentelle Psychologie, Universität Mainz, Germany; e-mail: landweh@uni-mainz.de)

If, for the letter T, up- and cross-stroke are equally long, the upstroke will appear longer, both visually and during haptic-tactile exploration (Tedford and Tudor, 1969, Journal of Experimental Psychology, 81(1), 199-201). Recently, I discovered another, purely haptic illusion with this stimulus: When subjects had to "grasp" computer images of individual lines of the T at their respective ends with a pretended thumb and index finger pincer grip, subjects scaled their responses to the length of the upstroke when grasping the cross-stroke, but were quite correct with the upstroke as target, independently of the orientation of the T (Landwehr, 2009, Attention, Perception, & Psychophysics, 71(5) 1197-1202). With regard to the visual illusion, I found an asymmetry in illusion strength depending on which stroke served as standard. Both effects can probably be explained in terms of neural detection mechanisms that register orientation and end-points of lines (cf. Caelli, 1977, Vision Research, 17, 837-841). Since the length of lines is misestimated only in contexts (Verrillo and Irvin, Sensory Processes, 3, 261-274), future investigations of the T-illusion(s) may profit from putting the T into variable contexts. I shall report on a project that focuses on conditions to either enhance or attenuate these illusions.

◆ **Pinhole viewing strengthens the Hollow-Face Illusion**

18 H Hill, T Koessler (School of Psychology, University of Wollongong, Australia; e-mail: harry@uow.edu.au)

The hollow-face illusion is the perception of a concave mask as a convex face when seen from beyond a certain distance. While a real three-dimensional mask is seen as concave at close distances, this is rarely if ever the case for frontal photographs or video of such masks. This suggests that monocular image information alone is insufficient to disambiguate depth. How is it that a three-dimensional mask is seen as concave at close distances when viewed monocularly? Here we tested whether ocular accommodation contributes by manipulating its availability using pinhole glasses. Pinhole viewing increased the distance over which the mask is seen as concave for both monocular and binocular viewing. This is consistent with accommodation disambiguating depth. This effect of pinholes alone was greater than that of monocular viewing alone and closing one eye had no additional effect when wearing pinholes. This suggests vergence may also disambiguate depth at short distance and be disrupted by pinhole viewing. Additional tests investigated the perceived flatness and distance of the illusory face. Observers reported that the illusion appeared more pronounced in depth when viewed through pinholes but that binocularity had no effect on this percept. Apparent distance was affected by both manipulations.

◆ **Intermediate-Level Motion Representations Account for the Hollow Face Illusion**

19 S Tschechne, H Neumann (Institute for Neural Information Processing, University of Ulm, Germany; e-mail: stephan.tschechne@uni-ulm.de)

Three-dimensional surface structure can be deferred from motion fields and their gradients [Treue and Andersen, 1996, Visual Neuroscience]. In the hollow face illusion (HFI) an unresolved convex/concave ambiguity leads to the percept of a concave face mask being convex when viewed frontally. It has been argued [Heard and Chugg, 2003, Perception] that this demonstrates the use of top-down knowledge to override local feature interpretations. We suggest that local mechanisms of motion computation may already account for the illusory effect. We extend a biologically inspired model that incorporates early and intermediate stages of cortical motion processing to indicate rotations of rigid object around its axes [Raudies et al., 2013, NECO]. Network components sensitive to motion direction/speed, speed gradients and their nonlinear combination to motion curvature build a robust representation of the spatio-temporal input. The model is probed by input sequences with rotating facial masks. Simulated motion responses are integrated at the stage of nonlinear motion curvature cells [Orban, 2008, Physiology Review]. Motion curvature cells selectively respond to the apparent image motion gradient pattern, reflecting the HFI.

The major effect of the HFI can thus be accounted for by intermediate motion representations signaling motion gradients and curvature patterns.
[SFB/TRR62, DFG.]

◆ **Phantom pencil illusion**

20 Y Sugano (Faculty of Contemporary Psychology, St Pauls University, Japan; e-mail: oshitemairu09@gmail.com)

Looking into a black pipe, 45cm in length and 2cm in diameter, I found a new geometrical optical illusion. Under the condition of perceiving this phenomenon, the black pipe and the bright background are needed. When the observer sees through the flat plane using the pipe with one eye, he or she can perceive an ambiguous figure like a pencil without a lead. And then the figure juts up to the observer (inside the pipe). This is “phantom pencil illusion”. The "black" pipe is suitable condition for this illusion. This phenomenon is newly found in the research area of visual perception.

◆ **The Effects Of Stress on Body Ownership and The Rubber Hand Illusion**

21 N Cooper, J M Furlong-Silva, N O’Sullivan, M Bertamini (Department of Psychological Sciences, University of Liverpool, United Kingdom; e-mail: m.bertamini@liv.ac.uk)

To date, embodiment has been explored from the perspective of being a trait construct. However, intrinsic variation might exist in response to different contexts, and thus embodiment might also be studied from the perspective of being a state construct. We reasoned that stress might be one contextual variable that would induce variation in embodiment, and in this experiment, we studied the impact of stress on both objective and subjective measures of the rubber hand illusion. The rubber hand illusion was measured in participants before and after they completed the Trier Social Stress Test, under the deception that the research project was about interviewee communicative skills with regard to future employment prospects of Undergraduates. Subjective stress was measured before and after the interview. Participants who reported an increase in stress following the interview demonstrated increased proprioceptive drift towards the rubber hand, and they reported a subjectively stronger sense of the illusion following the interview. Both effects remained when trait stress was controlled for. The findings suggest that task related stress does impact on embodiment, and they point towards the rubber hand illusion as a useful paradigm within which to explore the interaction between stress and embodiment.

◆ **The differences of perception of Muller-Lyer and Ponzo illusions at sensorimotor**

22 **measurements**

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There is some evidence of changes in the strength of visual illusions at different stages of schizophrenia compared with normal adults. Other results show that the strength of visual illusions is strongly dependent on both the modality of reproduction and handedness in a haptic version. In the present experiment, the Müller-Lyer and Ponzo illusion figures were presented to volunteers on the touch screen in separate trials. Using the index finger of his/her right- or left-hand, the volunteer’s task was to trace along the two shafts (Müller-Lyer) or lines (Ponzo) in an initial memorization stage. The illusion figure was then blanked on the screen and the volunteer had to reproduce the shafts or lines from memory using their finger on the touch screen. In this reproduction stage the volunteer’s eyes were either open or closed. The results revealed that there was a significant haptic Müller-Lyer illusion during both the memorization and reproduction stages. In contrast, there was only evidence of a haptic Ponzo illusion during the reproduction stage. The magnitude of both illusions was higher when the volunteer’s eyes were closed. These results support the hypothesis that different factors or mechanisms are responsible for these two well-known visual illusions.

◆ **Spatial updating of the Müller-Lyer illusion**

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Spatial updating refers to the process of maintaining stable spatial representations, even as we move. By using a double-step saccade task, we tested the role of contextual information in the updating process. Subjects briefly viewed the Müller-Lyer illusion with a target at its endpoint (T-ML), while fixating at the other endpoint of the illusion. Next, the fixation point jumped to a position above or below

T-ML, orthogonal to the orientation of the illusion. After a delay, subjects had to make a saccade to the remembered position of T-ML. We tested whether the update contains information that is influenced by the illusion. While the amplitude of saccades parallel to the Müller-Lyer illusion is usually affected by the illusion, saccades orthogonal to the illusion are not [De Grave et al., 2006, Exp Brain Res, 175(1), 179-82]. Our results show systematic errors in the endpoint of the second saccade, in the direction of the illusion. Thus, the updated representation of T-ML was affected by the illusion, suggesting that positions are not coded in a purely retinotopic frame of reference, but are also based on contextual information. This demonstrates that spatial updating mechanisms for motor control do not resist visual illusions.

◆ **Bayesian Inference Underpins Perception of Length**

24 A Binch (Department of Psychology, The University of Sheffield, United Kingdom; e-mail: pcq09ab@sheffield.ac.uk)

Vertical lines are perceived as longer than horizontal lines, which forms the basis of the line-length illusion (LLI). It has been proposed that the LLI is a side-effect of the brain's attempt to compensate for the compression of line length that results from perspective projection of 3D lines onto the retina. However, this hypothesis depends critically on the assumption that observers have some knowledge regarding the amount of compression imposed on lines at different orientations. Such knowledge is implicit in the observer's perceptual prior, which ideally should match the natural statistics of line length. Accordingly, we estimated observers' perceptual priors, and found them to be almost identical to the natural statistics of length, suggesting that the computational reason for the form of this perceptual prior is to support Bayesian inference of length, based on the statistical structure of the natural world.

◆ **Traffic jam: a new method to reduce drivers' illusion of the road slope by drawing stripe patterns on the side walls**

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The spontaneous traffic jams occur as a result of the enhancement of fluctuations of velocity in a certain density of vehicles. Sag sections are one of the famous places where we observe such traffic jams. Although sag sections actually are going uphill, they incline moderately. Drivers do not realize that they are going up, and hence drive without accelerating appropriately. Accordingly, the sag section produces the fluctuation of velocity as a trigger of traffic jams and it is enhanced in a certain density. This trigger is considered as a result of visual illusion where drivers are not able to correctly judge the slope of the road and fail to realize that it is going uphill. This illusion is called visual illusions of a vertical gradient, and also observed on many actual roads such as Yashima Driveway in Japan. Apparently, methods to prevent drivers from incorrectly recognizing road inclination through visual illusions are essential to achieve the smooth flow of traffic, since the correct recognition will reduce the fluctuation of velocity. In this contribution we propose the stripe pattern to prevent drivers from the visual illusions of a vertical gradient and verify to what extent visual illusions can be controlled.

◆ **Footstep Illusion Art: Apparent Rotation Generated by Pure Translation**

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This paper studies an optical illusion called footsteps illusion evoked by constantly moving objects in front of stripes first found by Anstis in 2001. We consider mechanisms of this illusion, formulate the conditions for maximizing the strength of the illusion, classify the apparent motions into eight patterns according to the widths of a pair of objects and their distance, and create new illusion artworks by combining these eight patterns. Moreover we introduce apparent rotation generated by pure translation. In the case of footsteps illusion, the object is a rectangle. But in the case of apparent rotation, the object is a set of four thin and long rectangles forming a square, and the background is a grid consisting of mutually orthogonal stripe patterns. When the squares move in front of this background, the squares look as if they are rotating. Surprisingly, although the two squares have exactly the same shape, we can place them in such a way that they rotate in opposite directions: one rotates clockwise, while the other rotates anticlockwise. We will discuss why apparent rotation can be generated by pure translation.

◆ **Rating Riloids: the effect of curvature and luminance frequency on visual discomfort**

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Visual discomfort is the adverse effects of viewing certain stimuli including symptoms such as headaches, eyestrain and diplopia, and distortions of vision such as perception of illusory colours and movement (Wilkins et al, Brain, 1984, 989-1017). These stimuli differ in their statistical properties to those of natural images, which could be the root of the discomfort. We examine curved striped patterns based on op-art, which have been shown to be capable of inducing perceptions of illusory movement (e.g. Zanker, Hermens and Walker, Journal of Vision, 2010, 10(2), 1-14), which would be included as 'discomfort' according to some definitions (e.g. Wilkins, Jeanes, Pumfrey and Laskier, Ophthal. Physiol. Optics, 2001, 16(6), 491-497). Whilst Zanker et al argued that the illusory movement is caused by erroneous motion signals, it has been argued that striped patterns cause discomfort through excessive neural responses, 'hyperexcitation' (Juricevic, Land, Wilkins and Webster, 2010, Perception, 39(7) 884-899). We investigated the relative contribution of these accounts to subjective discomfort judgements. As visual discomfort subjective, we present two methods for its measurement: 2AFC and magnitude estimation, finding good agreement between both, and an effect of luminance frequency, but not curvature on perceived discomfort.

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◆ **Is the human initial preference for rounded shapes universal? Preliminary results of an**

28 **ongoing cross-cultural research**

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It has been claimed that humans show an initial negative bias towards sharp contoured objects [Bar and Neta, 2006, Psychological Science, 17(8), 645-648]. Said preference has been hypothesized to result from a primitive perception of sharp transitions in contour as conveying a sense of threat. A later report of significantly higher levels of activity in the amygdala when perceiving everyday sharp objects, compared to its curved counterparts, endorses this idea [Bar and Neta, 2007, Neuropsychologia, 45, 2191-2200]. However, it remains to be tested whether this is indeed a universal human trait and not culturally determined. In order to do this, we devised a forced choice experiment employing a subset of the stimuli previously used by Bar & Neta, in an attempt to minimize a possible bias caused by the novelty of certain objects. After replicating their findings with students from the University of the Balearic Islands, we carried out an experiment with local population in Ghana. Our results follow the trend that would be expected if the original hypothesis were correct, although the need to verify the results among different cultural backgrounds call for further research.

◆ **In search of Gestalt. Detectability of objects within cubist artworks enhances appreciation.**

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It is widely claimed that modern art is marked by perceptual challenge inducing ambiguity and uncertainty [e.g. Jakesch and Leder, 2009, The Quarterly Journal of Experimental Psychology, 62, 2105-2112]. Especially cubist artworks exemplify various degrees of indeterminacy which can be reduced by the detection of objects or figures. Such 'creation of order in disorder' is suggested to be linked to appreciation [f.i. Hekkert & Leder, 2007, in: Product aesthetics, Schifferstein and Hekkert, Amsterdam, Elsevier]. We present two studies revealing that indeed, we prefer challenging artworks that offer detection of Gestalt. Twenty participants rated 120 cubist paintings on liking and in a subsequent block on detectability of objects. In a second study, participants pressed a button when they detected objects within the artwork and another if detection was impossible. The first study revealed a strong relation between detectability and liking. Preference in the second study was higher the more often people detected objects in the artworks and the faster detection was reported. We argue towards a mechanism that allows us to derive pleasure from finding meaningful patterns motivating exploration in an ambiguous world.

◆ **Image and Image. An Investigation into Intericonic Processes.**

30 C Reymond (Visual Communication and Iconic Research, University of Applied Sciences and Arts FHNW, Switzerland; e-mail: clairereymond@gmx.net)

The process of pictorial perception is the content of many studies. However the contextual influence on images has not been deeply explored yet. This work examines the context-specificity and its impact on the perceived meaning of a picture and intends to answer two main questions: Does the interpretation of an image change when perceiving a single image compared to a paired picture? How can the types of connection between two images be differentiated? In systematic practical experiments square-cut chromatic photographs of identical size were put together in pairs. Through the variation of the pairs, in which one image remained constant and the other was replaced, it became evident that several forms of linkage can be distinguished: connections based on formal similarities of the portrayed objects, connections that bore witness to a more metaphorical quality, linkage by way of an emotion-transfer from one image on the other, and pairs developing a 'third image' revealing characteristics of both original pictures. The different ways of image connections and their impact on the pictorial meaning were tested on ten participants. The results confirmed distinguishable connection types and showed a clear influence on image meaning depending on the single vs. the paired view.

◆ **Who is the best Gioconda of them all? On the relativity of artistic quality caused by prior visual elaboration**

31 V Hesslinger, C-C Carbon (Department of General Psychology and Methods, University of Bamberg, Germany; e-mail: vera.hesslinger@uni-bamberg.de)

For centuries, the Louvre version of the Mona Lisa ("La Gioconda") has been attracting the interest of millions. Meanwhile covered by severely yellowed varnish, Leonardo da Vinci's masterpiece has actually lost its original brilliance of color and the visibility of several pictorial details. Still, most visitors are strongly affected by this specific outward appearance while they reject the nearly identical but much fresher looking sister painting owned by the Prado/ Madrid that shows the Mona Lisa in brilliant color and detail. To test whether this preference can be explained by a recent theory on aesthetic adaptation [Carbon, 2011, i-Perception, 2, 708-719], we asked 32 participants to assess the artistic quality of morphs between the Louvre and the Prado version within an elaboration-test-comparison-retest paradigm [see 'Repeated Evaluation Technique', see Carbon and Leder, 2005, Applied Cognitive Psychology, 19, 587-601]. Whereas they strongly favored morphs having a texture more similar to the well-known Louvre version before comparing Louvre and Prado version (T1), they rejected these morphs afterwards (T2) when they had elaborated the Prado version, but not the Louvre version during the initial elaboration phase. The experiment demonstrates the flexibility of the perception of artistic quality on basis of prior visual elaboration.

◆ **Effects of music on visual art: an eye movement study**

32 A Koning, R van Lier (Donders Institute, Radboud University Nijmegen, Netherlands; e-mail: a.koning@donders.ru.nl)

We investigated eye movements of participants watching paintings while listening to music simultaneously. The paintings were either from William Turner (landscape sceneries) or from Wassily Kandinsky (abstract art). The music was either classical (e.g Beethoven, Pastorale symphony 1st movement) or jazz (e.g. Move by Miles Davis). A rating experiment confirmed our intuitive notion that while classical music better fits landscape sceneries, jazz better fits abstract art. A second group of participants was presented with the same paintings (10 Kandinsky's and 10 Turner's) and musical excerpts (10 classical and 10 jazz excerpts) but now their eye movements were recorded. Two effects stood out. First, Jazz (but not Classical music) influenced the number of fixations with more fixations for Kandinsky's than for Turner's. Second, classical music (but not jazz) influenced mean saccade length, with shorter saccades for Turner's than for Kandinsky's. In sum, when looking and listening to works of art simultaneously, rhythmically dense music influences visual scanning with regard to frequency of eye movements while rhythmically sparse music influences visual scanning with regard to the amplitude of eye movements. In this way music differentially regulates eye movements and, with that, the exploration of a piece of art in time and space.

◆ **Appreciation of afterimages in contemporary art: an eye movement study**

33 R van Lier, U Guclu, A Koning (Donders Institute, Radboud University Nijmegen, Netherlands; e-mail: r.vanlier@donders.ru.nl)

The artworks of the Dutch contemporary painter Roland Schimmel appeal to various low-level visual processes like Troxler fading and afterimage formation. At exhibitions the paintings have been described with expressions like "a hallucinogenic experience" or a "dreamworld". The paintings are relatively large and comprise vague, near-isoluminant colors, with additional high-contrast black disks. When the eye fixates on a disk, the colors in the periphery tend to disappear (due to troxler fading), whereas the immediate surrounding of the disk is perceived with a glowing afterimage-halo (due to microsaccades). After a saccade, the faded colors reappear, whereas the afterimage of the black disk suppresses the weakly colored background. We performed an eye-tracking study and asked observers to either fixate or to look freely at the paintings. The participants also rated their appreciation of the paintings. While free-viewing, all observers alternated fixations at the black disks with fixations at the colored areas. Paintings were appreciated more in the free-viewing condition than in the fixation condition, and visual exploration (in terms of eye movements) appeared more pronounced for highly appreciated paintings. Appreciation seems to depend on the perceptually confusing interplay between the black disks' afterimage and the colored background.

◆ **Aesthetic evaluation of abstract symmetric patterns with broken symmetries**

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There are a number of factors which are known to influence aesthetic evaluation [Leder et al, 2004, British Journal of Psychology, 95, 489-508]. Concerning abstract black-and-white patterns, Jacobsen and Höfel [2002, Perceptual and Motor Skills, 95, 755-766] found symmetry to be the most important and complexity the second-most important factor. However, there are claims that small asymmetries can be beautiful as well [McManus, 2005, European Review, 13(2), 157-180]. Here, we investigated the influence of such minor asymmetries on the liking of abstract patterns. We created a new set of abstract black-and-white patterns, containing broken symmetric patterns, which are slightly different from corresponding fully symmetric ones. Because breaking the symmetry increases the complexity, we additionally included fully symmetric patterns, matched to the broken patterns by visual complexity ratings obtained in a pre-study. The resulting patterns were then rated on a 7-point scale for liking. Patterns with broken symmetries were significantly less liked than full symmetric ones – despite the corresponding increase of complexity. Therefore, we can confirm the result of Jacobsen and Höfel [2002] that symmetry is a stronger and more important factor than complexity, even when the difference in symmetry is very small.

◆ **Enhancing aesthetic pleasure for paintings with computer controlled LED illumination**

35 R Stanikunas, A Tuzikas, R Vaicekauskas, A Petrulis (Department of Computer Science, Vilnius University, Lithuania; e-mail: rytis.stanikunas@ff.vu.lt)

Paintings in the museums are displayed under various lighting conditions: day light, florescent, incandescent or more recent LED illumination. New computer controlled LED lamps [Zukauskas et al, 2012, Opt. Expr. 20(5), 5356-5367] could create safe light for paintings, simulate lighting conditions under which the painting was painted or create colour enriching illuminant which provides the most pleasant viewing experience. The present study was aimed to examine aesthetics of the paintings illuminated by computer controlled LED illumination. The LED lamps were installed at the M. K. Curlionis National Museum of Art to illuminate paintings with different condition: some were in good condition and others had changes in colour because of aging process. Through computer interface viewers were allowed to modify qualitative lighting parameters such as correlated colour temperature, saturating-dulling ratio and shift white light from Planck's locus. General public viewers and art experts were asked to customise LED lightning to increase visual aesthetics of the paintings. Art experts were asked to customise LED lighting to enhance colours for colour depleted painting. Results show that the viewers tend to enhance colour gamut for both types of paintings to achieve more visual pleasantness.
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◆ **Looking at images with an aesthetic orientation: What's special about it?**

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We often visually explore objects, other people, or our environments with the purpose of evaluating their aesthetic qualities. Although previous research has examined people's eye movements while exploring paintings, little is known about what makes this aesthetic way of looking at the world special, if anything. A long tradition within empirical aesthetics regards complexity as a crucial factor influencing the aesthetic appreciation of visual stimuli, but to what extent does it impact the way people explore images with an aesthetic orientation? In this talk we present an eye tracking experiment aimed at determining whether participants deploy specific exploratory strategies when asked to rate the beauty of visual stimuli (aesthetic orientation), and to compare them to those used when they are asked to appraise the complexity of the same stimuli (pragmatic orientation). Our results showed that participants' exploration patterns, as measured by fixation count and duration, were determined by a complex interaction of bottom-up processes, related with the degree of realism and artistry of the stimuli, and processes determined by the task (judging beauty or complexity). Our results also clarify the effects of different complexity dimensions on beauty and complexity judgments, as well as the temporal unfolding of such effects.

◆ **Empirical aesthetics from a haptic perspective: A functional model for haptic aesthetic processing**

37 C-C Carbon[1], M Jakesch[2] ([1]Department of General Psychology and Methods, University of Bamberg, Germany; [2]Faculty of Psychology, University of Vienna, Austria; e-mail: ccc@uni-bamberg.de)

Research in aesthetics typically focuses on a) pure visual and b) static phenomena leaving unanswered a great many questions on haptic aesthetics and from a dynamic view. The present paper discusses current models of aesthetic processing and integrates new findings from cross-modal and haptic domains addressing top-down processes and mere exposure effects. Based on these empirical findings and theoretical considerations with regard to haptic research, the paper develops a functional model of haptic aesthetics which is explained step-by-step. This model assumes a continuous increase of elaborative processing through three subsequent processing stages beginning with low-level perceptual analyses that encompass an initial, unspecific exploration of the haptic material. After a subsequent, more elaborate and specific perceptual assessment of global haptic aspects, the described process enters into deeper cognitive and emotional evaluations involving individual knowledge on the now specified haptic material. The paper closes with an overview of empirical findings which are integrated and critically reflected in the realm of the functional model.

◆ **Changes of statistical image properties during the creation of graphic artworks**

38 C Redies (Institute of Anatomy I, University Jena School of Medicine, Germany; e-mail: redies@mti.uni-jena.de)

Several recent studies of visual artworks have investigated statistical image properties, for example, complexity, self-similarity, the fractal dimension and properties of the spatial frequency spectrum [for reviews, see Graham and Redies, 2010, Vision Research 50, 1503-1509; Forsythe et al, 2011, British Journal of Psychology 102, 49-70]. However, little is known about how these aesthetic measures evolve during the creation process. In the present work, I calculated aesthetic measures for two series of lithographs by Picasso (Les Deux Femmes Nues, 1945/46; Le Taureau, 1945/46) that represent variations on a theme and change from naturalistic to cubist drawings. Moreover, I analyzed state proofs of 20 abstract artworks created by myself. During the evolution of Picasso's cubist drawings and the creation of the abstract images, complexity increased, as expected. The slope of log-log plots of radially averaged Fourier power increased to values between -2.0 and -2.6 during the creation process and within the series of Picasso lithographs. Strikingly, self-similarity remained relatively constant in all series. The aesthetic measures therefore reflect different aspects of the creation process. The present work sets the path for future, more systematic studies on how aesthetic measures change when artists create visual artworks.

◆ **Depth Structure Invariance in Mirror Reversed Paintings**

39 J Wagemans, D Gielen, A van Doorn, J Koenderink (Laboratory of Experimental Psychology, University of Leuven (KU Leuven), Belgium; e-mail: johan.wagemans@ppw.kuleuven.be)

Some painterly compositions are decidedly left-right polarized. Such paintings tend to appear very different when viewed mirror reversed, although it is hard to specify in which dimensions the difference is articulated. Here, we consider the depth structure of the pictorial scene. This is a likely target in a search for differences, because we already know that the spatial attitude of the apparent frontoparallel plane is very volatile, and depends both on observer and on viewing conditions. We used a pointing-in-depth task that may well be expected to be sensitive to such matters. We report results for many observers and two paintings taken from impressionist and symbolist art. Perhaps surprisingly, we find only minor differences between the intended and mirror reversed versions of the paintings. This appears in conflict with the fact that the two versions appear very different indeed. The depth structure is invariant with respect to pictorial mirror reversal. Apparently, the nature of the difference between these presentations is due to other factors than the layout of the scene in pictorial space.

◆ **Do first impressions count? – Influences on the perception of ambiguous pictures**

40 S Utz, C-C Carbon (Department of General Psychology and Methods, University of Bamberg, Germany; e-mail: sandra.utz@uni-bamberg.de)

The perceptual interpretation of a visual scene is dependent on many factors, e.g. experience, pre-activated schemes and attention, leading to ambiguous interpretations [Pomplun et al, 1996, Perception, 25, 931-948]. Here we extended typical research in this respect by integrating influences of personality factors on the perception of ambiguous pictures within an eye tracking setting. Twenty-one participants examined 30 ambiguous paintings with varying complexity and responded as quickly as possible to two alternative interpretations (I1 & I2). Response times (RTs) were measured and questionnaires testing the tolerance to ambiguity (IMA) and the Big Five personality traits (BFI-K) were applied. In contrast to previous studies, participants were not informed about the interpretations of each stimulus in advance. Eye movement data revealed distinct scan paths according to the respective interpretation. RTs of both interpretations correlated negatively with openness to experience (I1: $r = -.51$; $p = .018$; I2: $r = -.68$; $p = .001$). Interestingly, the ambiguity tolerance scales did not correlate with RTs. On average, participants with a higher degree of openness to new experiences interpreted ambiguous paintings much faster than those with a lower degree. The present study reflects the utility and limits of usual experiments in the targeted domain neglecting personality factors.

◆ **Beauty in abstract paintings: Adaptation effects and statistical properties**

41 B Mallon, C Redies, G Hayn-Leichsenring (Institute of Anatomy I, University Jena School of Medicine, Germany; e-mail: birgitmallon@gmx.de)

Visual adaptation is a well-known phenomenon, especially for relatively simple image features like shape, color or motion. In recent years, adaptation studies have also employed more complex features. For example, in face perception research, adaptation on gender [Troje et al, 2006, Journal of Vision, 6, 850-857], age [Schweinberger et al, 2010, Vision Research, 50, 2570-2576] and attractiveness [Rhodes et al, 2003, Psychological Science, 14, 558-566] has been demonstrated. Extending such studies, the aim of the present work was to explore whether perception of beauty is subject to short-term influences. As stimuli, we used images of abstract (non-figurative) art to investigate the adaptation to perceived beauty in objects not carrying any semantic content. Results revealed highly significant adaptation effects on perceived beauty. Additionally, we analyzed a variety of statistical features (self-similarity, complexity, anisotropy [Redies et al, 2012, Lecture Notes in Computer Science 7583, 522-531] and color, etc.) for correlations with subjective judgments on beauty in abstract images. We found highly significant correlations for self-similarity and several color measures. Our findings suggest that perception of beauty in abstract artworks can be modulated by short-term exposure to visual stimuli. We emphasize the contribution of self-similarity and color measures for the perception of beauty.

◆ **Subjective and Objective Measures of Drawing Accuracy and their Relationship to Perceptual Abilities**

42 R Chamberlain, C McManus (Clinical, Educational and Health Psychology, University College London, United Kingdom; e-mail: chamberlainrebeccas@gmail.com)

In 1943 Theron Cain studied art students' ability to draw a series of simple six-sided shapes, and found this ability to be correlated with formal drawing assessments at art school. This provided evidence that certain aspects of drawing accuracy can be quantified, and that performance on more straightforward

drawing tasks can predict drawing accuracy for more complex stimuli, propounding a role for perceptual sensitivities in an account of drawing ability. The current study sought to validate Cain's findings by assessing the relationship between drawing and reproduction of angles and proportions in a rendering and non-rendering task, and by exploring the validity of shape analysis techniques for measuring drawing accuracy. Cain's findings were found to be supported; the ability to represent simple angular and proportional relationships relates to higher level drawing ability in both rendering and non-rendering scenarios. Drawing accuracy determined by shape analysis methods was also found to be correlated with subjective accuracy ratings for the same drawings. These findings provide support for both the methodology and the theoretical implications of Cain's early empirical study into observational drawing accuracy and provide a framework for further investigation into the perceptual abilities underpinning accurate representational drawing.

◆ **Visual perception in virtual museums and galleries**

43 I Varhaníková (Faculty of Mathematics, Physics and Informatics, Comenius University, Slovakia; e-mail: varhanikova@sccg.sk)

Classical problem for creators of virtual museum is how to place showpieces in environment to utilize them to make the exploration of museum more interesting and if it´s possible interactive. This can be achieved by insertion of computing best views of exposed 3D models and it can be improved with using knowledge from visual perception. For example while searching the best or worst view on object we use combination of methods based on our pre-research questionnaires(Fig.1) and to gain the attention of observers we use rules from Gestalt psychology(Fig.2). Another goal of our research is oriented on virtual galleries. We would like to know where to place the observer so he can perceive the painting similarly to how artist intended(Fig.3). And for the detailed view and explanation of saliency parts of painting we created application Artscan(Fig.7). We are also interested in the frame of paintings and pictures. In our paper we examine how change of the frame influences the observer while viewing the painting(Fig.4) and how the position of frame in consideration of the picture changes the meaning of paintings(Fig.5). For this purposes we created application Framepower(Fig.6), where visitor can change the frames and position of object.

POSTERS : COLOUR

◆ **Contingent capture in color-variegated stimuli**

44 N Heise, U Ansorge (Faculty of Psychology, University of Vienna, Austria; e-mail: nils.heise@univie.ac.at)

Laboratory cueing experiments used monochromatic stimuli to confirm top-down contingent capture of attention by color (e.g. Folk et al., 1992). In these experiments, one critical aspect of everyday color search is missing: color variegation. This could be crucial: color-variegated targets cover color spectres and thus potentially overlap with irrelevant color cues. Additionally, top-down search settings for color-variegated stimuli could be more demanding to set up or maintain. Therefore contingent capture could be restricted to monochromatic stimuli. To understand whether contingent capture extends to color-variegated stimuli, we used photographs of fruits and vegetables as target and cues. Cues were either mean colors, randomized color spectra, or naturalistic color distributions of specific fruits and vegetables. We found contingent capture by color with all these cue types. The data provide support for contingent capture by color with color-variegated stimuli.

◆ **Optimizing the strength of the Watercolor Effect by varying the width of the inducing contours.**

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When a dark chromatic contour surrounds a lighter chromatic contour, the lighter color will assimilate over the entire enclosed area. This is known as the Watercolor Effect (WCE). Here, we measured its strength using Maximum Likelihood Difference Scaling (MLDS) as a function of luminance elevation of the inner contour. Five contour widths ranging from 6-24 arcmin were tested in separate sessions. An observer was presented with 3 luminances (a, b, c) of the stimulus contour. The task was to choose whether the strength of the fill-in color of stimulus b was more similar to that of a or c. The strength of the phenomenon increases with luminance of the interior contour. A stronger WCE was observed for an

intermediate contour width (15 arcmin) with a decrease in strength of color appearance as contour width increased or decreased. In a second experiment, a contour width of 15 arcmin was used with different ratios between the outer and inner contour. The strength of the filling-in color was reduced for unequal contour widths, suggesting that balance of widths plays an important role in the WCE. Our data suggest that the WCE is tuned for the size of the inducing contours.

◆ 46 **Early cortical interactions between chromatic and luminance signals: an ERP study of object classification**

J Martinovic, B Jennings (School of Psychology, University of Aberdeen, United Kingdom; e-mail: j.martinovic@abdn.ac.uk)

While luminance and chromatic pathways remain largely separate at subcortical levels, their signals are combined from V1 onwards. This event-related potential (ERP) study examined how luminance and chromatic signals combine in early cortical processing. Participants discriminated between Gaborised images of nameable objects, novel objects and patches of randomly scattered Gabors. These stimuli were presented at mean threshold or at twice the threshold. They excited either the luminance pathway alone, luminance and L-M pathways or luminance, L-M and S-(L+M) pathways. While classification accuracy for the three types of stimuli was comparable across pathways at threshold, increases in performance at suprathreshold were less pronounced for objects defined by the full combination of pathways. The first ERP component, an N1 peaking 200-300ms after stimulus onset, occurred earlier and had larger amplitude at suprathreshold for luminance only and luminance and L-M stimuli. The full combination at suprathreshold elicited only a shift in latency but same amplitude as at threshold. Object-selectivity in the N1 was found only for the full combination. Therefore, the addition of S-(L+M) information at suprathreshold might both suppress the amplitude gain mechanism of the other two channels and enhance sensitivity to some mid-level property of objects, relating to lower accuracy rates.

◆ 47 **Perceptual latencies for chromatic versus achromatic stimuli**

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Luminance (i.e. achromatic) information travels through the visual system faster than chromatic information. It has been demonstrated that simple reaction time is fastest to luminance stimuli and slowest to S-cone stimuli. Does luminance information generate the perceived appearance of a stimulus with less delay than chromatic information? Perceptual asynchrony was examined with a temporal order judgement (TOJ) task, a simultaneity (SJ) task and masking task (MOA). We offer an evaluation of the relative strengths of these experimental paradigms for investigating perceptual asynchrony, and discuss the potential for biases in TOJ and SJ tasks with these stimuli. Critically, the MOA task contrasts the time taken for the each of the pathways to come to threshold, making it suited for comparison to the RT task. The MOA results suggest that luminance information is available 15 ms before S-cone information, the slowest of the chromatic pathways.

◆ 48 **Color categories for red and blue in Serbian language**

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Categorical perception of colors (CPC) refers to the faster discrimination of colors that belong to different categories than colors within the same category. Here we investigated CPC in the Serbian language. Similar to Russian and Greek speakers, Serbian speakers distinguish lighter and darker blues. Serbian also has separate linguistic categories for dark and light red, which is very rare. Participants performed color discrimination tasks for blue and red conditions separately. This was followed by a naming task in which they had to put each presented color in one of the four color-categories (two blue, two red). We categorized trials as between- or within-category, relative to participant's individual color boundaries. Participants were faster when discriminating between-category than within-category colors. This advantage was present only for physically similar shades while all physically distant shades were discriminated equally fast. Finally, discrimination was faster for reddish than bluish stimuli. CPC was demonstrated for language specific color categories in Serbian. Faster discrimination of red vs. blue targets, a novel finding, could be consistent with the hypothesis that trichromatic color vision is specialized for perception of blood-related modulation of skin appearance.

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◆ **Colour categorization from colour opponency**

49 C A Parraga, I Rafegas Fonoll (Computer Vision Centre / Computer Science Department, Universitat Autonoma de Barcelona, Spain; e-mail: alejandro.parraga@cvc.uab.es)

There is a wide gap between our understanding of the physiology of the visual system and how the brain categorizes the elements that form a visual scene, reducing an extremely complex world to cognitively tractable proportions. In the colour domain, this reduction is large indeed: from nearly 2 million distinguishable colours to the near 30 categories that can be recalled by a normal subject. In this work we try to bridge this gap by presenting a parsimonious model that decodes colour opponent signals (such as those entering the visual cortex from the LGN) and constructs a set of universal chromatic categories consistent with perceptual evidence. To adjust the model we psychophysically measured the boundaries between nine categorical regions, revealing their intrinsic 3D shape in a colour-opponent space. Our psychophysical paradigm was designed to collect most data points where they are most needed: the categorical boundaries. The model itself consists of a set of ellipsoidal volumes generated by adding and weighting chromatically opponent input signals. We believe such an approach may help bridge the gap between what is known about the physiology of the visual system and current pragmatic solutions to the colour categorization problem.

◆ **Influence of color induction on unique hues**

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The chromaticity of the surround influences the perceived color of a stimulus. Here, we investigated systematically how induction affects the appearance of unique hues. Subjects performed unique hue settings by adjusting the chromaticity along the azimuth angle in cone-opponent color space of a 2-degree patch presented on isoluminant backgrounds of different chromaticities. Backgrounds were either neutral gray or had a chromaticity corresponding to one of eight hue angles with fixed cone contrast with respect to the gray background. Unique hue settings on the neutral gray background were in agreement with the distributions of unique hues [Valberg, 2001, Vision Research, 41, 1645-1657; Webster et al, 2000, Journal of the Optical Society of America A, 17, 1545-1555]. On chromatic backgrounds, unique hue settings were shifted systematically away from the inducing background chromaticity. The amount of hue shift depended on the difference in hue angle between the inducer and the respective unique hue. This dependence was similar to the induction effects measured when subjects performed asymmetric matching of stimuli with chromaticities not corresponding to unique hues. These results suggest that unique hue percepts are influenced by the same mechanisms as the percepts of other colors.

◆ **Paolo Bozzi's line drawing transparencies in colour**

51 D Zavagno (Department of Psychology, University of Milano-Bicocca, Italy; e-mail: daniele.zavagno@unimib.it)

In 1975 Paolo Bozzi (1930-2003) published a paper in which he showed the possibility of creating impressions of transparencies with simple achromatic line drawings. Being this year the 10th anniversary of his passing, a selected core of his works – originally written in Italian – are now being translated into English, to be published in a book with original commentaries by other fellow scientists who were his students and/or interested in the topics of those papers. To commemorate Bozzi, I present a sneak preview of my comments written for his line drawing transparency paper, in which I discuss Bozzi's findings and extend them to the domain of colour. By introducing colour, I demonstrate the generality of Bozzi's findings and the strength of the effects, which are determined solely by figural structure, articulation, and good continuation, three themes that underlie Bozzi's original work.

◆ **Twisted Paths in Color Space**

52 J Koenderink, A van Doorn, V Ekroll (Laboratory of Experimental Psychology, University of Leuven (KU Leuven), Belgium; e-mail: jan.koenderink@ppw.kuleuven.be)

In many computer applications a user has to produce a color. On a laptop this conventionally implies a "color picker". Color pickers allow the user to trace a path to some color Q, of course, starting from some (arbitrary) color P. The user traverses a path from P to Q in color space. In doing this, the user is constantly aware of the visually present color (some color R say) and the imagined target color Q, the starting color P being a thing of the past. The choosen direction of advance in color space at any moment depends upon the color picker's interface and on the abilities of the observer. We monitor orbits (both in colorspace and time) taken by observers to move – as efficiently as they can – between pairs of

locations in color space. We find spectacular differences between interfaces. We interpret this in terms of the degree to which the interface approximates the observer's "natural mental image" of color space. This type of study yields a novel and very detailed insight into the structure of "mental color spaces".

◆ **Colour perception induced by Bidwell disk under chromatic illumination**

53 A Svegzda, R Stanikunas, A Daugirdiene, H Vaitkevicius, R Bliumas, V Kulbokaite, A Novickovas (Department of General Psychology, Vilnius University, Lithuania; e-mail: algimantas.svegzda@ff.vu.lt)

The Bidwell effect is a convincing colour illusion phenomenon. In the original setup the half white, half black disk is illuminated with a white light and rotated few times per second. A hole is made between these two sectors and the red light is placed behind the disk. The greenish-blue colour is perceived despite the physical red light shining through the hole. We investigated colour perception of Bidwell effect under various chromatic illuminations. The back side of the disk was lit by red, green and blue LED lights, while the front side of the disk was illuminated by the same LEDs plus amber and neutral D65 light mixed from those four LEDs. We explored all possible fifteen colour combinations for the front and back side of the disk. It was found that perceived subjective colors of Bidwell stimuli is affected by colored illumination. Moreover, the same LED illumination from the front and the back sides of the disk produces temporal lightness modulation which induces different color perception comparing with constant lightness illumination.

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◆ **Visual Perception of color blending in spot lights**

54 A Teupner (OSR CT RI LMO, Osram GmbH, Germany; e-mail: a.teupner-ext@osram.com)

The objective of the project is the development of a standardized evaluation method which describes color homogeneity in light spots according to visual preferences. It is difficult to make forecasts up to which level spot lights need to have uniform character in order to match obervers' expectations. The described experiment covers several spatial color distributions integrated into spot lights. The far field homogeneity of the smoothed spots is classified by four factors: hue, chroma, pattern composition and symmetrical plane. In the experiment, the spot lights are shown successively pairwise to compare each other and state, which one appears more comfortable to the observer. Through the combination of the parameters, the majority of the effecting values is identified. First results: the asymmetric pattern, absolute number of hues and uneven pattern are more disturbing as absolute chroma, whereupon pattern symmetry has high impact. Furthermore, the level of color blending which is not perceivable compared to the reference value is detected. Subsequently, the perception is compared to mathematical color evaluation methods which show notable divergences. The results of the experiment will be the basis for new evaluation techniques based on visual preferences.

◆ **Extending the watercolour illusion: differential effects of real colours versus afterimage colours**

55 S Hazenberg, R van Lier (Donders Institute, Radboud University Nijmegen, Netherlands; e-mail: s.j.hazenberg@donders.ru.nl)

We investigated filling-in of coloured afterimages [Van Lier et al., 2009, Current Biology 19(8), R323–R324] and compared them with filling-in of real colours in the watercolour illusion [Pinna et al., 2001, Vision Research 41, 2669–2676]. We used shapes comprising two thin adjacent undulating outlines of which the inner or the outer outline was chromatic, while the other was achromatic. The outlines could be presented simultaneously, inducing the watercolour effect, or in an alternating fashion, inducing coloured afterimages of the chromatic outlines. In Experiment 1, using only alternating outlines, these afterimages triggered filling-in, revealing an 'afterimage watercolour' effect. Depending on whether the inner or the outer outline was chromatic, filling-in of a negative or a positive afterimage colour was perceived. In Experiment 2, simultaneous and alternating presentations were compared. During simultaneous presentation, filling-in induced by the inner chromatic outline was strongest. In contrast, during alternating presentation, the strength of filling-in induced by the outer chromatic contour appeared to be strongest. Comparisons with Experiment 1 showed that, while afterimage filling-in induced by the inner contour depended on the luminance contrast between the interior of the shape and that outline, afterimage filling-in induced by the outer contour appeared more robust.

◆ **A new psychophysical technique to measure chromatic afterimages**

56 W Bi, J L Barbur (Applied Vision Research Centre, City University London, United Kingdom; e-mail: wei.bi@alumni-oxford.com)

The purpose of this study was to measure the strength and duration of chromatic afterimages in normal trichromats and in subjects with congenital colour deficiency. A new, test was developed to measure the strength and duration of perceived chromatic afterimages in normal trichromats and in subjects with red-green deficiency. A typical chromatic afterimage experiment involves two stages: a rapid, four-alternative, forced-choice stage followed by a staircase test. The rapid phase yields a good approximation to the true threshold. This stage improves the efficiency and accuracy of the subsequent staircase procedure. The measured afterimage strength in normal subjects follows an exponential decrease to the subject's normal colour detection threshold; colour deficients, on the other hand, exhibit a very large initial threshold followed by rapid decrease to a constant threshold that is generally much larger than in normal trichromats. A model will be presented to account for the difference in results measured in subjects with congenital colour deficiency. The results suggest that in addition to the two chromatic mechanisms involved in normal trichromats, the perception of afterimages in subjects with congenital colour deficiency is also affected by achromatic mechanisms.

◆ **Visual search is affected by chromatic adaptation**

57 K Sakata (College of Art and Design, Joshibi University of Art and Design, Japan; e-mail: sakata00031@venus.joshibi.jp)

The results of visual search tasks are known to be affected by local chromatic adaptation, which brings the target into focus without affecting the visual perception of other distracters (Theeuwes and Lucassen, 1993). However, chromatic adaptation extending to a broad area on the retina would not affect the results of these tasks because of its equal effects on the colour appearance of all the elements, i.e. the target and the distracters . The results of this study showed that the location of the adaptation stimuli on the chromaticity diagram influences the results of colour-based distinction between the target and distracters. The adaptation stimuli would affect all 3 types of receptors on the retina and the colour-vision mechanisms which usually accept visual information through the eyes. These results were discussed in the context of the loci of chromatic adaptation, i.e. the three cone system on the retina and the higher chromatic mechanisms in the cortex.

POSTERS : FEATURES, CONTOURS, GROUPING AND BINDING

◆ **Near their thresholds for detection, shapes are discriminated by the angular separation of their corners**

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Observers make sense of scenes by parsing images on the retina into meaningful objects. This ability is retained for line drawings, demonstrating that critical information is concentrated at object boundaries. Information theoretic studies argue for further concentration at points of maximum curvature, or corners, on such boundaries suggesting that the relative positions of such corners might be important in defining shape. In this study we use patterns subtly deformed from circular, by a sinusoidal modulation of radius, in order to measure threshold sensitivity to shape change. By examining the ability of observers to discriminate between patterns of different frequency and/or number of cycles of modulation in a 2x2 forced choice task we were able to show psychophysically that difference in a single cue, the periodicity of the corners (specifically the polar angle between two points of maximum curvature) was sufficient to allow discrimination of two patterns near their thresholds for detection. We conclude that patterns could be considered as labelled for this measure. It might be conjectured that a small number of such labels might be sufficient to identify an object.

◆ **What causes errors in a near-threshold forced-choice shape orientation task?**

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Recently, we found that false responses in a near-threshold 8-alternative forced-choice Landolt C shape orientation task are not equally distributed, as would be assumed by psychometric theory. Rather, response orientations adjacent to the displayed orientation occur 3 times as often as other

false orientations. To better understand this effect, we assessed how precisely subjects are able to assess the orientation of threshold-sized Landolt Cs in the first place. We presented threshold-sized stimuli at 360 possible orientations to 15 subjects, who provided an orientation response at 1-degree resolution via a rotary knob that controlled an orbiting orientation marker on the screen. The width of the response distribution relative to the display orientation was determined by fitting a raised cosine. The standard case of 8 orientations and an above-threshold 360-orientation task served as references to disentangle response imprecision from perceptual resolution. In all subjects, the response distribution in the near-threshold 360-orientation task extended substantially into what would be the catchment intervals of the adjacent orientation responses of an equivalent standard 8-orientation task. The data quantitatively explain the unequal distribution of false responses in the 8-orientation task and suggest that perceptual resolution, rather than response imprecision, is the dominant factor.

◆ **Vertical preference in judgment of line orientation**

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Visuospatial skills influence human functioning at many levels. Lines of different orientation are the basic features of visual objects. Therefore detection of their orientation is one of the key points of human visuospatial abilities. The aim of our study was to explore brain mechanisms of detection and identification of environmental spatial characteristics. In the first experiment 24 subjects (12 men) have to estimate the proximity of oblique lines to the vertical, horizontal, 45º and 135º axis. The stimuli were eight grids of oblique lines, and difference between adjacent grids was 9º. We found that RT was higher and accuracy was lower for ambiguous orientations (27º and 72º). The erroneous assessments of line orientation tended to be more vertical. Reaction time (RT) was lower and accuracy was higher for oblique lines that were closer to vertical in comparison with horizontal axis. In the second experiment the same subjects have to differentiate grids of horizontal and vertical lines, and RT was lower for vertical in comparison with horizontal orientation. Finally, our findings show predominance of the vertical axis in human visual system. We suppose that vertical preference is fundamental characteristic of visual spatial operations.

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◆ **Tolerance for local and global differences in the integration of shape information**

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Objects are often identified visually by the shape of their profiles, and global encoding of shape is implied by evidence that, for boundaries distorted from circular by sinusoidal modulation of radius, information is integrated across cycles. The relationship between evidence for integration within regular shapes and encoding of complex profiles has, however, been neglected. In this psychophysical study, rather than attempting to reconcile competing models of shape analysis, we chose to manipulate the function describing the boundary modulation to explore the envelope of integration. In a previous study we identified that detection threshold scales with modulation frequency and, hence, maximum orientation difference from circular. Exploiting this property we first rectified the modulating function and showed that integration was preserved, but also that patterns with rectified and un-rectified modulation could not be discriminated at threshold demonstrating that continuity of curvature is not critical to integration or object recognition. Second we concatenated cycles of different frequency by matching their orientations at zero crossings of the sine function to create irregular patterns. Again integration was preserved. Mirror images of an irregular pattern could not, however, be discriminated at threshold suggesting that the two patterns are not represented by different spatial templates.

◆ **Combination of texture and color cues in shape detection and identification**

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The contribution of cue summation effects for local saliency and form completion was studied in a combined feature target detection and figure shape identification task with orientation, spatial frequency, and color cues. Double-cue targets were combinations of the orientation cue with either spatial frequency or color. The double-cue gain in detection was much larger than predicted by the assumption of cue independence only for combinations of orientation and spatial scale, but not for combinations of orientation and color. In the figure identification task, however, performance was at the same levels for both types of cue combinations, and much larger than predicted by the assumption of cue-independence. The findings show that saliency of local texture elements and local border detection on the one hand and

grouping of elements into global shapes concerns both feature pairings to different degrees. Orientation and color strongly are only weakly fused to enhance local border saliency, but strongly fused to enhance element grouping within a figure surface. Orientation and spatial scale are optimal segregation cues which render a figure visible mostly by enhancing its texture borders.

◆ **Independent texture and luminance processes in globally pooled shape**

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Shapes can be defined by paths of luminance contrast or by boundaries of texture contrast. Global pooling of local information around an explicitly-defined luminance contour has been shown to occur but this has not been demonstrated for texture segmentation defined shapes. Research has also suggested texture and luminance cues-to-shape are integrated by the visual system for detection of the presence of a shape; it was of interest if this extended to shape discrimination. Shapes deformed from circular by a sinusoidal modulation of radius defined either by a luminance-border, texture-border or both these cues were used in a two-interval force choice task. As number of cycles of modulation increased, discrimination thresholds fell rapidly indicative of global pooling for all stimuli. Also, thresholds for shapes defined by both cues matched predictions based on an independent-cue vector sum of individual thresholds. We surmise that local elements around a contour are processed globally by a shape-detection mechanism but integration was not combined across shape-cues. This suggests the existence of separate mechanisms for luminance-defined and texture-defined contours.

◆ **The role of familiarity and predictability in contour grouping**

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Research using snake-shaped Gabor contours has shown a gradual decline of contour detection performance with eccentricity, but for circular contours integration is hardly affected even at highly eccentric locations. This discrepancy in findings could involve many factors such as contour length, shape closure, and unidirectionality of curvature, but in the present study we focus on two factors which we termed predictability and familiarity. Firstly, with circular targets the observer knows beforehand what shape to expect, whereas in snake detection tasks different shapes are typically presented on each trial rendering the precise contour shape unpredictable to the observer. Secondly, the circle is a familiar shape that is immediately apprehended and labeled as a circle. Participants detected snake-like stimuli in central and peripheral vision. We manipulated familiarity by extensively training with one particular snake shape, specific to each observer. We varied predictability by alternating trial blocks with a single shape and blocks with different shapes and found a clear beneficial effect of predictability regardless of eccentricity. Familiarity effects varied between observers, but further research will try to determine whether these effects are partly confounded with characteristics (e.g., complexity, spatial extent) of the specific snake shapes chosen as familiar for the different observers.

◆ **A role for Gestalt principles of organisation in shaping preferences for non-natural spatial and dynamic patterns**

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Cognitive models of categorisation processes have dominated our understanding of how preferences are shaped. It is argued that experience with faces and objects influences preferences such that the category prototype, or average, is the most preferred of the category set (e.g. Halberstadt & Rhodes, 2003, Psychological Bulletin & Review, 10, 149-56). This preference for the average is thought to occur as it best reflects how information is represented in memory, thus is 'easy on the mind' (Winkielman et al. 2006, Psychological Science, 9, 799-806). However, the role of more perceptual principles of information processing on determining our preferences is less well known. We investigated how perceptual organisation may influence preferences for patterns by manipulating the degree of 'order' in a continuum of static (Experiment 1) or dynamic (Experiment 2) dot patterns and asked participants to rate exemplars using a Likert scale. We found consistent effects across experiments, with greater preferences for more ordered static exemplars in which grouping principles of 'proximity' and 'good continuation' were maximised, and for more correlated motion in dynamic exemplars in which 'common fate' was maximised. Our findings suggest that Gestalt principles of perceptual organisation may play a significant role in shaping preferences for visual stimuli.

◆ **Contour integration in static and dynamic scenes**

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Contour integration is an integral part of visual information processing which requires observers to combine colinear and cocircular edge configurations into coherent percepts. Psychophysical experiments have shown that humans are efficient in these tasks, reaching considerable contour detection performances for presentation times as low as 20ms. These studies have mainly used static stimulus which are briefly flashed, or shown for an extended period. However, in nature we rarely encounter brief presentations of a visual scene, rather, we observe a scene for an extended period and develop a coherent picture which takes into account dynamic elements. It is unknown how contour integration is performed in dynamic situations, and how top-down cognitive processes, such as selective attention, interact with bottom-up feature integration. We investigate contour integration in dynamic stimulus configurations where slowly rotating Gabor elements generate dynamic contours at different times and locations on a screen. Preliminary results suggest that contours are better detected in flashed presentations of 200ms than in long presentations containing the same arrangements. Thus, contours 'pop-out' only when there is a sudden change in a visual scene, from a grey background to a field of Gabors, but require sustained attention to be detected in dynamic scenes.

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◆ **Perceptual grouping without awareness: Collinear contour facilitation or surface filling-in?**

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A regular, grouped Kanizsa triangle has been shown to break through interocular suppression faster than an ungrouped, random Kanizsa triangle [Wang et al., 2012, PLoS ONE, 7(6): e40106]. In an earlier neuropsychological study Conci et al. [2009, Neuropsychologia, 47, 726-732] showed that low-level collinear contour facilitation and high-level surface filling-in both contribute separately to a reduction in extinction in patients with visual neglect when viewing Kanizsa stimuli. Since Wang et al. (2012) did not include control conditions similar to Conci et al. (2009), it is not clear whether the Kanizsa triangle broke through suppression due to collinear contour facilitation or higher-level surface completion mechanisms [Kogo et al., 2010, Psychological Review, 117(2), 406-439]. In this study, we tested whether a Kanizsa square would break through interocular suppression faster than a random Kanizsa square while controlling for collinear contour facilitation. Our results suggest that collinear contour facilitation contributes to the benefit of a grouped Kanizsa square breaking through suppression compared to an ungrouped Kanizsa square. Since the percept of an illusory figure is presumably gradually built up along the ventral stream, our results tap into the debate to what extent interocular suppression diminishes processing along the ventral stream.

◆ **Levels of perceptual learning as reflected by eye movements**

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At what neuronal level does perceptual learning take place? There seems to be evidence for the involvement of both low- and high-level mechanisms; however, it is not known how these mechanisms are involved at the different stages of learning. We addressed this issue by combining eye-tracking and psychophysical techniques while subjects were practicing a contour integration task [Gervan et al., 2011, PlosOne, 6(9), 255725, 1-9]. 18 adult subjects completed the 5-day-long training. Psychophysical thresholds were estimated on each consecutive day, while eye movements were registered on Day1 and Day5. Behavioral data show perceptual learning by Day5. There were also significant changes in eye movement pattern by the end of training. The most intriguing eye movement changes occurred in the psychophysically also most relevant range: at those difficulty levels that were below and just above the psychophysically measured threshold (75% correct). As a result of learning, the number of fixations decreased at the difficulty level just above threshold, while pupil dilatation remained the same. At the difficulty level below threshold, the number of fixations increased as well as pupil dilatation. We interpret this pattern of results as clear indication for different neuronal mechanisms being involved at the different stages of learning.

◆ **Comparison of manual and fixation reaction time for non-accidental properties in contours**

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Non-accidental-properties (NAPs), such as intersection, parallelism and symmetry are regularities in the arrangement of 2D image features that are used to infer 3D spatial relations. Here we compare the reaction-time (RT) for eye-movement and manual-response data for various NAPs. We used one or two Gaborized contours (snakes) embedded within an array of equi-density Gabor distractors. Contours were defined exclusively by good continuity of the oriented Gabors elements on a straight or curved path. The two contours could occur in four configurations: Intersection, Parallel, Symmetric or Random, in any of the four quadrants of the screen. We measured the benefit of NAPs w.r.t. the relations between the two snakes over mere probability summation, both on initial detection and on a subsequent recognition task. We examined effects on eye-movement (EM-RT) time for first-fixation near the snake and on manual-response (M-RT) time for a key-press to indicate detection. We found significant effects of NAPs on EM-RT and M-RT with specific trends suggesting different levels of cognitive processing for various NAPs from its first detection by EM to action.

◆ **Peripheral contour integration is biased towards convex contours**

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Integrating local edges into spatially extended contours is a fundamental step in perceptual organization. This process of contour integration is known to depend on the local alignment and relative spacing of adjacent contour elements. To investigate how the global curvature polarity of a contour influences contour integration in the visual periphery, we embedded circular arc contours in a field of randomly positioned Gabor elements. These contours could appear at three different eccentricities and were either convex or concave with respect to the central fixation position. Participants were instructed to indicate whether the contour appeared in the right or in the left half of the display. Peripherally presented convex contours were detected faster than concave contours at all three eccentricities.

◆ **Perceptual grouping as Bayesian estimation of mixture models**

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We propose a Bayesian approach to perceptual grouping in which the goal of the computation is to estimate the organization that best explains an observed configuration of image elements. We formalize the problem as a mixture estimation problem, where it is assumed that the configuration of elements is generated by a set of distinct components ("objects"), whose underlying parameters we seek to estimate (including location and "ownership" of image elements). An important aspect of this approach is that we can estimate the number of components in the image, given a set of assumptions about the underlying generative model. We illustrate our approach, and compare it to human perception, in the context of one such generative class: Gaussian dot-clusters. In two experiments, we showed subjects dots that were sampled from either two (Exp. 1) or three Gaussian clusters (Exp. 2). In both experiments we manipulated the distances between the clusters in order to modulate the apparent number of clusters. Subjects were asked to indicate how many clusters they perceived. We found that numerical estimates based on our Bayesian model closely matched subjects' responses. Thus our Bayesian approach to perceptual grouping, among other things, effectively models the perception of cluster numerosity.

◆ **Selectivity of second-order visual mechanisms sensitive to the orientation modulations**

72 **revealed by masking**

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Second-order visual mechanisms process information on modulations of primary visual features such as contrast, orientation and spatial frequency. Here we show psychophysical research of visual mechanisms sensitive to the orientation modulations. Test stimulus has a carrier that is texture composed of horizontally oriented staggered Gabor micropatterns, and envelope that is sinusoidal modulation function of orientation. Masks are test textures with different envelope shifts in: i) phase (0-180 deg), ii) orientation (0-90 deg), iii) spatial frequency (from -2 to +2 octaves). Using masking, 2-alternative forced-choice procedure, and staircase method we revealed bandpass tunings of mechanisms in question

to orientation, phase, and spatial frequency of modulation. Spatial frequency selectivity is consistent with some current data [Reynaud and Hess, 2012, Exp Brain Res, 220(2), 135-145; Westrick et al, 2013, Vision Res, 81, 58-68], but is inconsistent with our previous results obtained in analogous study using stimuli with vertical orientation of a carrier [Babenko et al, 2012, Proceedings of 10th International Conference "Applied Optics", P. 331-334]. We suppose that this discrepancy in results is due to the fact that in 2 experiments there are different ratios of carrier-envelope orientations, and these ratios play important role in perception of second-order orientations.

◆ **Quantitative prediction of figure-ground assignment with difference of gathering**

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Many factors such as area, symmetry and convexity affect “figure-ground assignment.” However, most such factors can predict the assignment only qualitatively. This study was conducted to quantify figure-ground assignment, introducing a new index: “difference of gathering.” Gathering, which is the index estimating the degree of denseness of components, is formularized with a concept of zero-mean normalized cross-correlation of adjacent pixels. A difference of gathering values is assumed to indicate a difference of strengths as a figure between competing components such as black and white. We hypothesized that the response ratio to regard a component having a larger gathering value as a figure increased as the difference of gathering values increased. In an experiment conducted to test the hypothesis, we used a square pattern comprising white and black dots. We manipulated the gathering values of the elements and those in specific areas. Participants responded which component or area was perceived to contain a figure. Results demonstrated that the ease in the figure-ground assignment increased linearly as the difference of gathering values increased. The results implied that a difference of gathering values for different elements in a pattern strongly affects the figure-ground assignment.

◆ **The effect of stimulus predictability on the representations of local elements**

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Recent fMRI studies suggest that the presence of top-down predictions about a stimulus is associated with a reduced activation in lower brain regions in which more local features are represented, and increased activation in higher brain regions in which more global aspects of objects are encoded. This finding suggests that top-down feedback from higher areas reduces the activity in lower areas. There are several interpretations for this observed reduction in lower-level activity, involving either a weakening of neural representations of local image elements or a "sharpening" of local representations in which irrelevant lower-level activity is reduced. In this study, we aimed to investigate which interpretation is more likely. More specifically, we measured contrast perception of local gratings which are either part of a spatio-temporally coherent or incoherent stimulus configuration. Preliminary results indicate that the coherency of the stimulus reduces contrast discriminability, suggesting that neural representations of gratings are weakened when these gratings are part of a predictable spatio-temporal configuration.

◆ **Visual repetition facilitates the detection of Gaborized shape outlines**

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Repetition underlies important aspects of visual perception such the recognition of patterns, object grouping and pictorial sequences (e.g., film reels/cartoon strips). These contain spatially separated shapes which have perceptual relationships with each other. Such shapes may appear as being instances of different objects, or alternatively as distinct instances of the same object. How do spatially distinct but repeating images of objects visually interact with each other, and yield such different perceptual effects? To begin to answer this question, the effect of shape repetition on detection of shape outlines was examined. A set of Gaborized outlines (animate, inanimate, geometric shapes, etc.) were embedded in backgrounds of randomly orientated Gabor patches. Four conditions were presented to participants with flanker outline shapes on either side of the target outline (control, 0-X-0; triplet, X-X-X; flanking doublet, Y-X-Y; unique, Y-X-Z). Discrimination thresholds for detecting the presence of an outline (2-AFC) were measured while varying the orientation noise of the contour Gabor elements (adaptive staircase). Repetitions of identical outline (triplet, X-X-X) produced significantly lower thresholds in comparison to all other conditions. The data further suggests that while the type of outline appears to have no significant effect on thresholds, specific inter-object similarities (symmetry) may be relevant.

POSTERS : 3D VISION, DEPTH AND STEREO

◆ **Shape constancy from binocular disparity with self-motion in depth**

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Previous studies have investigated the three-dimensional shape constancy from binocular disparity using objects which were static or moved in the direction of depth and found that depth was overestimated at near distances. However, little is known how we perceive disparity-defined object when we actively move toward or away from it. The purpose of this study is to examine the shape constancy from binocular disparity with observer's self-motion in depth. The observers moved forward and judged whether the cylindrical object appeared expanded or compressed relative to the perceived shape at the start position. The disparity of object changed in real-time according to the position of observer using magnetic motion tracker. The results showed that the shape appeared constant when the simulated depth within object was compressed as observers moved toward the object. Thus, overestimation of depth at near distance was also found with self-motion. We also examined the shape constancy in the condition in which only two frames were shown at start and end position. The results showed no significant difference between two-frame and continuous display, suggesting that the continuous disparity change with self-motion does not have a significant effect on accurate depth perception for shape constancy.
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◆ **Velocity tunings of binocular disparity channels for very large depth**

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It is well-known that an excessive disparity causes diplopia and unclear depth impression. However, we recently found that target motion facilitates stereopsis for very large depth [Sato et al., 2007, ITE Technical Report, 31(18), 25-28, Sato and Sunaga, 2012, Perception, 41 ECVP Supplement, 71]. To examine the velocity tuning and temporal summation of the responsible mechanism, we measured contrast sensitivities for depth discrimination as functions of target velocity and duration using one-dimensional DoG targets (the space constants of positive and negative Gaussians were 68 and 102 arcmin, respectively, corresponding to 0.16 c/deg peak special frequency). Two targets (one above and the other below the fixation point) were presented for 0.05, 0.1, 0.2, 0.4, or 0.8 s in a raised cosine temporal window and 4.8 deg crossed and uncrossed disparities were given to one and other targets. These targets drifted horizontally in the opposite direction with velocity of 0, 7.5, 15, 30, 60, or 120 deg/s. The results show that the highest sensitivity was obtained at around 15-30 deg/s when the duration was long while velocity tunings were much broader when the duration was short. It appears that a dynamic mechanism tuned to that velocity range mediates stereopsis for large depth.

◆ **Visual-motor reaction to 3D motion: binocular parallax VS motion parallax**

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To measure visual-motor reaction (VMR) to 3D motion we used an experimental set which was consisted of slopped tray, two sensors and electronic timer. In the 1st experiment we estimated a "power" of motion parallax (MP).The task of a subject (S) was to trace visually the metallic ball moving from the left to the right along the tray towards the "finish gate" and to stop the timer when the ball passed through the gate. In front of the gate the velocity of the ball was 0.5 m/s. We measured the time delay of VMR. In the 2nd experiment we estimated a "power" of binocular parallax (BP). In this conditions S looked along line of stimulus motion while St moved towards his eyes. Thus only BP could be used to determine the moment of the ball "finishing". 12 Ss were participated. 10 Ss showed the clear superiority of MP. Results of 2 Ss were not significant. We conclude that MP is more effective tool in motion perception than BP.

◆ **Stereoscopic fusion with gaze-contingent blur**

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Away from fixation, blur is a more precise cue to depth than binocular disparity, and the visual system relies on the more informative cue when both are available [Held et al, 2012, Current Biology, 22(5):426-431]. Furthermore, the presence of correct defocus diminishes visual fatigue while viewing stereoscopic

stimuli [Hoffman, et al, 2008, JoV, 8(3):33,1-30]. These findings suggest that defocus plays an important role in the perception of simulated 3 dimensional scenes. We examine how the time-course of binocular fusion depends on depth cues from blur and stereoscopic disparity in natural images. Light field photographs of natural scenes taken with a Lytro camera were used to implement a real-time gaze-contingent stereoscopic display with a natural distribution of blurs and disparities across the retina. Depth cues from disparity and blur were independently manipulated while observers were required to locate the closest or furthest region in depth under free or guided viewing and press a response button when the 3D image fused. The time-course of perceptual fusion increased with depth away from the initial fixation plane and was shorter when blur and disparity cues were coherent. These results suggest that informative distributions of retinal blur facilitate depth perception in natural images.

◆ **Impact of absolute disparities on motion in depth perception in stereoscopic displays**

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It is known that motion in depth (MID) in stereoscopic displays is perceived due to absolute and relative disparity changes. Studies on MID perception are generally focused on relative disparity changes so does the link between absolute and relative disparities remains unclear. In order to clarify this link, it appears essential to identify the role played by the absolute disparity in MID perception. For this purpose, we employed the motion aftereffects (MAE) to test the hypothesis that visual system contains neural populations tuned to 3D directions of motion generated by absolute disparities. Observers were exposed to 20 min of a moving cross followed by 1 min of fixation on a stable cross. Subjects were instructed to discriminate the cross motion in depth during the 21 min of exposure. As changing of absolute disparity stimulates the oculomotor system (OS), OS changing was also assessed. Preliminary results indicate that no MAE could be observed whereas oculomotor changes appear. MID perception using absolute disparity seems mainly based on OS. Moreover, if in future studies a discrepancy is observed between MID perception using relative disparity and MID perception using both disparities, our results suggest that absolute and relative disparities interact and affect each other.

◆ **A New Evolution of 'X' from Motion**

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Human vision has ability to perceive 3-D from motion, which has been studied widely as "'X' from motion". As for the 'X', 'depth', 'shape', 'structure' and 'surface' has been reported; recently, as a new category 'volume' was added [Cheng, 2010, Optical Review 17-5 439-442; Cheng, 2011, Optical Review 18-4 297-300]. We performed the observation experiment of moving random dot pattern stuck on different types of surface; then it was confirmed that 'depth' 'shape', 'structure', 'surface' and 'volume' were perceived successfully. We examined not only the continuous real motion but also the velocity field produced by the cyclic display of multi-stroke apparent motion sequence and suitable ISI [http://www.lifesci.sussex.ac.uk/home/George_Mather/TwoStrokeFlash.htm]; then, we found that 'depth', 'structure', 'surface', and 'volume' can be perceived almost the same as in the real motion. The authors inferred that the velocity field might be produced by the anomalous motion in still figure [http://www.ritsumei.ac.jp/ akitaoka; Idesawa, 2010, Optical Review 17-6 557-561] and 3-D perception could be obtained. Some potential figures were found in Kitaoka's collection. We examined the picture of suitably distributed anomalous motion elements with different properties in direction and strength; although the perception was faint, the potential pictures excepting 'volume' were generated.

◆ **Depth perception in peripheral vision**

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Many studies have demonstrated that people can perceive depth in central vision, but they cannot perceive it in peripheral vision. We used two-dimensional and three-dimension-like images to examine whether depth perception is possible in peripheral vision. The participants were 21 university students. The experimental design involved 4 shapes (2 two-dimensional shapes [a circle and a hexagon] and 2 three-dimensional shapes [a sphere and a cube]) in 8 presentation positions (60°, 45°, 30°, and 15°; in the left and right directions, with the front as 0°). Participants were shown 32 images, in random order and asked to discriminate the two-dimensional and three-dimensional figures. The results showed that participants could significantly discriminate these images at angles ranging from 15° to 60° on both left and right sides, indicating that they could perceive depth in peripheral vision within these limits.

The correct response rates were over 70% for almost all shapes and positions, except for the cube in the 60° position. These results show that the perceived shape of an object might be related to its depth perception in peripheral vision, since presentation positions with higher angles were associated with lower accuracy for identification of cubes and hexagons.

◆ **The dependence of 'Change Blindness' on depth of visual objects positioning**

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This research takes into consideration methodological aspects of the "change blindness" (CB) phenomenon - a failure to notice significant changes in objects that are located within a visual field due to perceptual interruption [Rensink, O'Regan & Clark, 1997, Psychological Science 8 (5), 368-373.]. A Virtual Reality system (Cave) was used in the study. Stimuli [Mikhaylova, Gusev & Utochkin, 2012, Perception 39, p. 102] included 3D scenes that contained visual cubes. In the first series all the cubes were positioned at the same depth (same references on axis Z), while in the second series at different depths (Z parameters for cubes were different). We developed a formula for the Virtools 4.0 environment, which allows varying the depth of the cubes' positioning while remaining their positions at the frontal plane (axes X, Y). Participants were asked to detect a shift of one cube within the visual scene. The results showed that the visual search was more effective for cubes with different depth arrangement. Thus the inclusion of depth as an additional cue within a visual scene reduces the severity of CB by structuring the scene.

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◆ **Higher-resolution image enhances subjective depth sensation in natural scenes**

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Although enhancement of sensation induced by the images of ultra high-definition TV has been reported [Emoto et al, 2006, Displays][Masaoka et al, 2013, IEEE Transactions on Broadcasting], the effect of such high-definition images remains unclear. To examine if the resolution of image could be a factor of the improvement for the depth sensation of objects in natural scenes, we conducted a series of subjective assessment experiments under a variety of viewing conditions: 4k format projector with 193-inch screen, 28-inch 4k LCD display and 4.38-inch HD LCD display were used, and the viewing distances were 250cm, 105cm and 33cm (approximately 80°, 30° and 15° in the field-of-view) respectively. Fifteen short movies of natural scenes with higher- and lower-resolution were presented in random order. As a result of the experiments with 30 participants, the mean rating across viewing conditions for the sense of depth in objects, depth in space, realness and fineness showed significantly higher when the images displayed with higher resolution than that with lower resolution. These findings implicate that an improvement of image resolution could enhance the depth sensation in natural scenes as well as the depth perception from the luminance contrast in synthetic images [Tsushima, Komine, Hiruma, ECVP 2012].

◆ **Countershading camouflage: using light for concealing 3D information**

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Animal camouflage can only be understood by considering both the environment in which the animal lives and the predator from which it is trying to hide. Countershading is the phenomenon where animals are darker on the dorsal surface and lighter on the ventral surface. There are at least two accounts of how countershading may work. The background matching (BM) hypothesis suggests the animal should be hidden against its background (e.g. viewed from below, the light sky; from above, the dark ground). In essence, this is a two-dimensional (2D) problem. Second, countershading may deliver obliterative shading (OS), so that 3D 'shape-from-shading' cues, from self-shadowing, are minimised. Here, we used computational modelling to test how optimal BM and OS depends on the time of the day, or light intensity. We modelled the interaction of light with 3D shapes and found the optimal countershading for different luminance distributions. Further, we analysed and compared what countershading patterns

would result from both specialist (single lighting condition) and compromise optimisation strategies (across a number of lighting conditions).

◆ **Characterising the 'zone of good stereoscopic depth perception' in 3d stereo displays**

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Vergence-accommodation conflicts in 3d stereoscopic displays cause not only discomfort/fatigue, but also degraded stereoscopic depth perception. Previous research has estimated the range of conflicts that result in comfortable viewing [Shibata et al., 2011, Journal of Vision, 11(8):11]. Less is known, however, about the tolerance of perception of stereoscopic depth to vergence-accommodation conflicts, although this too is important for creating effective stereo media. We used a multiple-focal-planes stereoscopic display to present stimuli at a range of screen distances (1.3, 0.7 & 0.1 dioptres; 0.76, 1.43 & 10 m), and varied vergence-specified distance to present stimuli in-front-of and (where possible) behind the screen, creating a range of vergence-accommodation conflicts. We characterised stereo depth perception in each condition by measuring stereoacuity thresholds. Stereoacuity deteriorated similarly with conflict at all three screen distances. Performance fell off most rapidly for stereo stimuli behind the screen, suggesting there is a larger perceptual tolerance to vergence-accommodation conflicts (in dioptres) for stimuli nearer than the screen. At 1.3 D screen distance, stereoacuity 'behind' the screen was significantly reduced within Shibata et al.'s (2011) estimated 'comfort zone'. This suggests that data on stereo performance, and not only discomfort, should inform the creation of optimal stereoscopic content.

◆ **3D Surface configuration effect in Glass Pattern perception**

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We investigated how 3D surface configuration affects 2D Glass pattern perception. Glass patterns consist of randomly distributed dot pairs, or dipoles, whose orientations follow a geometric transform. The stimuli were concentric Glass patterns (2.5deg radius) consisted of dots (2.3' x 2.3') with 4% density. The 3D surface modulations were achieved by manipulating binocular disparity of dots. There were two 3D configurations: slanted (the first order), where the depth changed linearly from one side to the other, and concave/convex (the second order), where the depth changed with a projectile centered at the fixation. We measured the coherence threshold for detecting the Glass patterns on these surfaces at 75% accuracy with a 2AFC paradigm. In the first order conditions, the coherence threshold was always the same as that measured on the frontoparallel plane regardless the slant of the surface. In the second order conditions, however, the threshold increased with surface curvature linearly on log-log coordinates. Our result suggests that the Glass pattern detection is viewpoint invariant and thus may have an underlying 3D representation. In addition, such 3D representation is the first order rather than the second order surfaces.

◆ **Surface slant can be perceived from orientation disparities**

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We show that people can use differences in the orientation of features in the two eyes' images directly to perceive slant. We presented observers with binocular stereograms that depicted surfaces slanted in depth. These were either correlated (i.e. the luminance of corresponding features was matched across the two images) or anticorrelated (i.e. one eye's image was replaced by its photographic negative). The majority of observers were able to reliably report the direction of slant in both cases. In contrast, no observers were able to accurately make a simple 'near/far' depth judgement for our anticorrelated stimuli. We modelled the responses of cortical cells that are tuned to different orientations in the two eyes to our stimuli. Our results show that the responses of populations of these neurons provide sufficient information for the visual system to discriminate the direction of surface slant. Models of binocular processing in the visual cortex that rely purely on differences in the position of corresponding features need to be extended to account for the encoding of multiple kinds of disparity. The finding that stereopsis also makes use of orientation disparities is consistent with the orientation tuning properties of cortical binocular neurons.

◆ **Environment maps and the perception of shape from mirror reflections**

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Perceiving the shape of a smoothly curved mirror surface is a challenging task because the image intensities are determined both by the surface shape and by the surrounding environment. Here we extend our recent study of the perception of qualitative shape from highlights and mirror reflections [Faisman and Langer, Journal of Vision (in press)] by more closely examining how shape percepts of mirror surfaces depend on the parameters of the environment map. We generated smooth, bumpy terrain surfaces using computer graphics and presented them slanted as a floor or ceiling. The surfaces were illuminated using environment maps that included 1/f noise and a near regular soccer ball pattern. The brightnesses of these environment maps were modulated with low frequency spherical harmonics to give them a dominant direction which produced a shading-like effect similar to soft gloss. Our main finding is that varying the dominant direction of the environment brightness relative to the global slant of the terrain significantly affected subject's performance in judging qualitative shape. The effect is similar to (but subtly distinct from) the classical prior for light from above for matte surfaces.

◆ **Disparity statistics inform the perception of material for glossy objects**

90 A Muryy, A Welchman, R Fleming (School of Psychology, University of Birmingham, United Kingdom; e-mail: a.a.muryy@bham.ac.uk)

Specular ("glossy") objects create stereo-signals with specific properties that differ significantly from Lambertian ("matte") surfaces. Does the visual system use these stereo-cues to identify the material properties of objects? We identified potential stereoscopic cues to surface gloss by calculating the disparity fields generated by irregularly shaped Lambertian and specular objects. We found that specular objects give rise to specific and unusual features: 1) specular disparity fields may have discontinuities and un-fusible or barely fusible regions; 2) patterns of vertical disparities are quite unusual in their magnitude and distribution. We then conducted psychophysical judgments of gloss to test the role of these signals in material perception. Using a specialised rendering procedure, we systematically morphed between stimuli with Lambertian vs. Specular properties, while holding monocular cues constant. We presented stimuli from this morphing space to obtain thresholds for "glossy" and "matte" appearance (8 participants, adaptive threshold estimation procedure). We found that objects appeared glossy in a large area of this morphing space, consistent with the use of the unusual disparity signals, but not with the true physical properties of specular reflection. Additional analysis found limited evidence for interocular intensity and contrast sign differences, suggesting 'binocular lustre' is less important than disparity properties.

◆ **Anisotropy of texture gradient as depth cue**

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Since Gibson's (1950), it has been documented that texture gradient generates a slanted surface. To demonstrate this effect, people have normally used texture gradient in which texture density is low at the bottom, is high at the top, and is gradually changed along the vertical axis of the pattern. Our inquiry was to ask whether the effect of texture gradient is independent of orientation of the pattern and of orientation of observer's head. For this purpose, we used a texture gradient pattern that was consisted of filled circles or of cobble stones. In either pattern, size of texture elements and the space interval between the neighboring elements were changed in perspective and orientation (normal vs. upside-down) of the pattern was also changed. Each of 18 observers viewed each pattern through a head-mounted display while leaning the head downward, keeping it upright, or leaning it backward. The observer judged apparent slant of the surface generated by texture gradient. We found that 1) apparent slant did not change with the change in head position and 2) apparent slant was steeper for the upside-down pattern than fort the normal pattern. We discuss this finding in terms of the anisotropy of visual space.

◆ **Depth cue priors are modulated by stereoacuity**

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Although depth cue combination has been studied extensively using virtual displays, few studies have examined how these cues affect perception of real depth. Additionally, previous research on depth cue integration has usually relied on subjects who have excellent stereoacuity (<100 arc seconds); however,

it has been suggested that cue combination may be observer-dependent [Oruç et al, 2003, Vis Res, 43, 2451-2468]. We conducted an experiment to determine whether differences in stereoacuity affect the influence of multiple depth cues by using a stimulus that evoked 'real' depth - a slanted circle, in a darkened box, viewed through an aperture. The presence of a disparity gradient and texture-defined slant were independently modulated. Observers were asked to reproduce the retinal projection of the shape viewed in the box. The influence of cues to depth were determined by measuring the degree of shape constancy elicited. It was found that the stereo cue dominated shape judgments for all participants, regardless of stereoacuity. However, when the stimulus was viewed monocularly, presence of the texture cue increased shape constancy only for individuals with poor stereoacuity. This suggests that the prior probability distribution of monocular cues to depth is dependent on the ability to use binocular disparity.

◆ **Fast switching of cue integration weights**

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To perceive three-dimensional (3D) structures of external environments, the visual system uses multiple depth cues such as binocular disparity and texture gradient. These cues are extracted in individual modules and then integrated. An optimal way to integrate multiple cues is the maximum likelihood estimation (MLE) [Ernst and Bulthoff, 2004, Trends in Cognitive Sciences, 8, 162-169]. The MLE provides the most precise depth estimate by weighting cues according to those reliabilities. Although various experiments indicate the brain employs the MLE to integrate multiple module/modality information, some open questions remain. Here we examined whether the brain can change the integration weights immediately after we see a new scene. Cue reliability depends on scenes and objects as well as the nature of the cue itself. In the experiment, three slanted natural images with disparity and texture cues were presented in random order. Observers had a prior knowledge concerning the images, and, if the visual system could change the weights rapidly, they should perceive the image slants with minimal variance in every trial. The result showed that observer's judgments were as precise as the MLE and suggests that the visual system switched the weights appropriately according to what image was presented in each trial.

◆ **Computational model of neuronal system for local and global stereo vision**

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Current widely accepted models of stereo vision address the coding of either disparity or visual direction; moreover, no biologically plausible models combine processing of both. These properties of stereo vision are still not computationally explained: diplopia, allelotropia, stereoacuity phenomena, impact of differences in monocular contrast on the perception of object location in 3-D space. We propose a computational model of neuronal system for the determination of both stereo depth and visual direction. Introduced binocular analyzer consists of a set of local analyzers (LAs) that map information to a global system. Each LA provides encoded disparity and direction of light centroid presented in a small part of visual field. LAs combine signals from the four types of Gabor-like monocular neurons that have corresponding receptive fields. Here global system constructs representation of the entire binocular visual field. Proposed model embodies all properties of the energy model, and is supported by our and other authors' experimental data. Model explains: exponential decrease of stereoacuity while object is moving away from horopter, influence of interocular contrast's differences on perceived direction and depth, phenomena of the allelotropia and diplopia. [Postdoctoral fellowship is being funded by European Union Structural Funds project "Postdoctoral Fellowship Implementation in Lithuania"]

◆ **A Bayesian approach to half-occlusions**

95 M Zannoli, M Banks (School of Optometry, University of California, Berkeley, CA, United States; e-mail: marinazannoli@gmail.com)

In natural scenes, distant surfaces are often occluded to one eye by nearby surfaces. Binocular disparity cannot be computed in these monocular regions, but those regions are nonetheless perceived at specific depths. To better understand how depth is estimated in this situation, we developed a probabilistic model of depth estimation with half-occlusions. The model incorporated probability distributions associated with occlusion geometry and a zero-disparity preference and distributions associated with the observed azimuth and blur of the monocular dot. We tested the model's predictions in a set of experiments. In each experiment, a monocular dot was presented to the side of a binocular occluder. Participants indicated the

perceived 3D location of the monocular dot by adjusting a binocular probe until the perceived azimuths and depths of the dot and probe were equal. We first asked whether the fixation distance relative to the occluding surface mattered to the perceived depth of the monocular dot. We found that it did; when the fixation distance was closer than the occluder, the perceived depth of the dot decreased and when the fixation distance was farther, the dot's perceived depth increased. We next asked whether the sharpness of the monocular dot mattered. We found that it did not affect the average perceived depth but did affect the variance of depth settings with higher variance associated with greater blur.

◆ **View Point Tricks for Visual Distortion of Photographs**

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Photographs sometimes give an impression of the depth of a scene different from reality. One of basic origins of this kind of visual phenomena is the difference between the lens center at which we take photographs and the view point at which we see the photographs. We investigate the relationships between the visual distortion of the depth perceived from a photograph and the difference of the view point from the lens center from a geometric point of view. In particular, we point out that there are two main tricks by which we can give incorrect impressions of the depths through photographs. One is the use of special lenses such as telephoto lens and wide-view lens. The other is the overlay of two or more photographs into a single image. A single image lacks information about the depth of a scene, and hence there are infinitely many possible interpretation of the depth. However, we usually perceive the depth without ambiguity. This nature of our perception may be explained by the assumption that we prefer the most symmetric shape. This assumption together with the tricks of the view point can explain the visual phenomena of depth distortion.

◆ **Binocular LITE**

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As part of "Project LITE: Light Inquiry Through Experiments" we have developed software that assists individuals in investigating for themselves a variety of binocular vision phenomena. The software is written using HTML5 and is designed for smart phones and MP3 players, such as the iPhone and iPod running the Apple iOS, and similar devices running the Android operating system. We have also developed an inexpensive binocular viewer for use with these phones. The goal is to help the user explore: binocular rivalry; binocular lustre; depth perception arising from binocular disparity; dichoptic color mixing; persistence of vision; and other features of binocular vision. Included in our new software applications suite is a controllable random dot stereogram (RDS) application that permits user selection of various images, textures, and image separations; a stereoscopic vision app; a Pulfrich effect demonstration; a thaumatrope; and an app for exploring auto random dot stereograms (ARDS). Preliminary studies of binocular color mixing using our viewer and apps suggests that "dichoptic" or "cortical" yellow perception occurs in more than half of the trial subjects tested. All of our software can be found at http://lite.bu.edu. Project LITE is supported in part by NSF Grant # DUE - 0715975.

POSTERS : CATEGORISATION AND RECOGNITION

◆ **Perception of the dynamic form of flames in hearth fire**

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Fire has long been a significant part of the visual environment; it may therefore be encoded by specialised neural representations. We investigated, for the first time, the processing and representation of moving flames by measuring recognition performance of dynamic fire. Our delayed match-to-sample task consisted of first presenting a target clip of a log fire in a grate, followed by two similar test sequences. Observers reported which sequence contained the target. Recognition performance decreased with test sequence length (from 74% to 66%; $p<0.001$) but increased with target length (from 60% to 72%; $p<0.00001$), which may reflect false positives due to stimulus periodicity. Separately, we manipulated the colour, direction of video playback and spatial orientation between sample and test. Normal recognition performance (76%) was not affected by changing colour ($p>0.14$), indicating that observers did not rely on chromatic information. Performance was reduced to 72% by reversing playback direction ($p<0.02$), indicating observers were sensitive to dynamic form; it fell to 66% under spatial inversion ($p<0.001$),

showing that subjects were not using a generic motion cue. Neural representations of fire can therefore be easily matched across the colour domain, and less so under spatial and temporal inversion.

◆ **Inhibitory effect of forward mask on target stimuli recognition: The influence of**
99 **mask-target categorical compatibility**

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In the behavioral and EEG experiments we have investigated the impact of information provided by forward masking stimuli on recognition of the target ones. Thirty-eight healthy subjects had to recognize the complex images of two categories (animals and objects) in situations where the target and masking stimulus (SOA=50 ms) belonged to the same or different categories (categorial "compatible" or "incompatible" pairs). It was found that forward masking evoked reduced accuracy and increased RT of recognition. These effects were more pronounced for compatible pairs compared to incompatible ones. It should be emphasized that the impairment was more marked for animals as compared to objects. Mask-target compatibility was also accompanied by an increase in RT dispersion and its interquartile range, suggesting that compatibility affects the central decision component of recognition. This assumption is partly supported by reduced amplitude of N200 and P300 waves of visual ERPs mostly in frontal and parietal cortical areas. We suggest that forward mask is not perceived passively, but its processing may suppress target processing, and the greater the similarity of the stimulus and mask the more pronounced inhibitory interaction.

◆ **Visual processing: First come, first served...**
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How can humans achieve complex visual discriminations with saccadic response times below 150 milliseconds [Kirchner and Thorpe, 2006, Vision Research,46,1762-1776], given all the latencies in the visual system? Humans may achieve fast reactions by using arrival times of the first spikes (temporal order code), or else employing a very short integration interval (only a few spikes). To address the latter possibility, we distributed image presentation to several frames. Subjects indicated in a 2-AFC task which of two natural scenes contained an animal. Stimuli were presented either in one frame (5ms) or segregated over 3 frames (15ms). Subjects responded either by moving a throttle lever (experiment 1) or by saccadic eye movements, either without (experiment 2) or else with (experiment 3) a temporal gap (200ms) between fixation point disappearance and stimulus onset. In experiments 1 and 2, segmentation had no effect, ruling out a pure temporal order code. In contrast, experiment 3 revealed a clear decrease in performance for presentations segmented over 15ms. Our results indicate a temporal integration time window of 5 to 10ms, corresponding nicely with earlier reports on temporal resolution of roughly 10 ms [Kandil and Fahle, 2001, European Journal of Neuroscience,13,2004-2008].

◆ **Frequency dependent object recognition**
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Visual information in object recognition is selectively processed already at the retina. Magnocellular and parvocellular ganglion cells differ especially in spatial frequency tuning. Earlier research showed information from low-pass filtered pictures reaches cortical areas associated with decision making faster than high frequency information [Bar et al, 2006 PNAS, 103(2), 449 – 454]. Here we present data, how the recognition speed and accuracy in ultra-fast object recognition is influenced when the stimuli are frequency-filtered through a wavelet-transformation and presented from low frequencies to high frequencies and in opposite direction. Observers viewed images containing an animal as targets against distractor pictures of natural scenes without an animal. In the first part we presented pictures with predefined frequency components (low, middle, high) for 15 ms on a 200 Hz Monitor in a saccadic 2AFC task to establish baseline performance. In the second part of the experiment observers viewed three consecutive frames, containing different spatial-frequency in each frame. All six possible permutations for low, middle and high were tested separately. The comparison of the presentation order revealed a significant advantage for presentation sequence from low-to-high over high-to-low in performance. Presentation in opposite order to natural arrival times may disturb perception.

◆ **Does coarse-to-fine spatial frequency processing depend on object categorization task?**

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Visual object processing follows a coarse-to-fine sequence imposed by fast processing of low spatial frequencies (LSF) and slow processing of high spatial frequencies (HSF). We tested how these different spatial frequency ranges may support categorization at superordinate (e.g. "animal") and more specific levels (e.g. basic-level, "dog"), and whether any such dependencies are reflected in signals recorded using EEG. We used event-related potentials and time-frequency analysis to examine the time course of object processing while participants performed a grammatical gender-classification task (which generally forces basic-level categorization) or a living/non-living judgement (superordinate categorization) on every day, familiar objects. The objects were filtered to contain only LSF or HSF. We found a greater positivity and greater negativity for HSF than for LSF pictures in the P1 and N1 respectively, but no effects of task on either component. A later, fronto-central negativity (N350) was enhanced during gender-classification relative to superordinate categorization, indicating that this component relates to semantic or syntactic processing. Induced gamma-band activity was not influenced by task or spatial frequency. Our results indicate early differences in processing of HSF and LSF content which did not interact with categorization task, while later responses reflected higher-level cognitive factors.

◆ **Time-course of object detection and categorization in fragmented object contours**

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In order to investigate the temporal dynamics of different perceptual decisions, we measured performance (RT and accuracy) in a detection and three categorization tasks (Natural and Artifactual categorization, superordinate-level categorization and basic-level categorization) using fragmented object contour stimuli taken from Panis, De Winter, Vandekerckhove and Wagemans (2008). We manipulated fragment length (short versus long) and fragment type (curved versus straight), and measured the complexity of the overall shapes, to study how these visual factors influence the time to take a decision in each task by analyzing the shape of the RT distributions using event history analysis. In all tasks, the main effects of stimulus length and complexity were significant for fast responses, consistent with the idea that fast responses are based on early representations following bottom-up processing. For short fragments and slower responses, we found a hazard advantage for curved versus straight fragments when the task was basic-level recognition, consistent with the idea that late responses reflect top-down influences from activated high-level candidate representations on visual grouping processes during difficult recognition. These findings suggest that the top-down influence in object recognition is dependent on the abstraction level of the category.

◆ **The experience of beauty of different categories of objects**

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The purpose of the present study was to compare the structures of the experience of beauty of different object categories. The experience of beauty was measured by the check-list of 137 descriptors (e.g. pleasant, harmonious, exciting, etc). Seventeen participants were asked to mark the descriptors which well described their experience of beauty of five categories: (1) Humans, (2) Animals, (3) Architecture, (4) Nature, and (5) Things. Distributions of the frequencies of 137 adjectives for five categories were inter-correlated. Analyses have shown significant positive correlations between Humans and Animals (.70), Architecture and Things (.69), and Architecture and Nature (.30). Humans and Animals were negatively significantly correlated with Architecture (-.45 and -.42) and Things (-.40 and -.43). Cluster analysis revealed (a) one cluster which included descriptors with high frequency across all categories, and clusters which included the descriptors specific for (b) Humans, (c) Humans and Animals, (d) Architecture and Things and (e) Nature, Architecture and Things. These results suggest that the structure of the experience of beauty is category specific. Two wider coalitions of categories were specified: Living beings (Humans and Animals) and Artificial objects (Architecture and Things). Nature was placed between those coalitions, but slightly closer to Artificial objects.

◆ **Emergent recognition of objects hidden in degraded images in the absence of explicit top-down information**

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It is well known that recognition of severely degraded images such as two-tone 'Mooney' images is facilitated by top-down processing, in which priorly given information about the hidden objects play an effective role in recognizing the defective object images. Even in the absence of any explicit top-down information, however, we can still recognize the hidden objects during continued observation of the images in an emergent manner accompanied by a similar feeling to 'Aha!'experience. Neural mechanisms of this kind of recognition without the top-down facilitation are poorly understood. Since this phenomenon is characterized by longer latencies ranging in seconds, we measured time for subjects to recognize objects hidden in degraded images. We found that the time follows a particular exponential function related to severity of image degradation and subject's capability, which could be determined independently each other. This function was well accounted for by a theoretical model based on feature-combination coding of visual objects, in which neurons representing the object's features removed by the image degradation show stochastic activation to complement the representation of the object to be recognized. The present results suggest that the stochastic process working on feature combination coding of objects underlies the emergent recognition.

◆ **Individual differences in boundary extension and false memory**

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Boundary extension is a phenomenon wherein participants remember seeing more of a scene than was actually shown (Intraub & Richardson, 1989, Journal of Experimental Psychology: Learning, Memory, and Cognition, 15(2), 179–187). Previous studies have found that participant characteristics (e.g., age, personality, and psychiatric disorder) influenced boundary extension. However, individual cognitive differences in boundary extension have not been investigated. Although boundary extension is a perceptual issue, it is indirectly evaluated by measuring memory. Thus, in this study, the relationship between the magnitude of boundary extension and false alarm rate in the DRM paradigm (Roediger & McDermott 1995, Journal of Experimental Psychology: Learning, Memory and Cognition, 21(4), 803-814) was investigated. Participants rated the magnitude of boundary extension in close-up pictures and wide-angle pictures and performed a word recognition task according to the DRM paradigm. We found a positive significant correlation between the magnitude of boundary extension in close-up pictures and false recognition rate of lure targets. This result suggests that boundary extension could be interpreted as false memory and affected by the memory ability of the participants.

◆ **Are Low-spatial Frequencies Sufficient for Unaware (Masked) Priming of Face-Sex Discrimination?**

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We tested whether the magno-cellular projection is sufficient to support awareness independent face processing. On the basis of the magno-cellular projection's exclusive sensitivity for LSF bands, we expected that peripheral, masked HSF primes would not be processed, but that masked unfiltered primes, masked LSF primes, and unmasked HSF primes would lead to a congruence effect. In five experiments, all of these predictions were confirmed. We found that masked unfiltered primes led to a congruence effect and that masked HSF primes did not (Experiment 1). We showed that masked unfiltered primes and masked LSF primes both led to significant congruence effects of about similar size (Experiment 2). We demonstrated that unmasked HSF primes created a congruence effect, while masked HSF primes failed to create a congruence effect (Experiment 3). Control Experiments concerning balancing the prime faces for spatial frequency contents (Experiment 4), and further for the contrast (Experiment 5) confirmed the above findings. Our findings are in agreement with an origin of unaware vision in processing along the magno-cellular pathway.

◆ **Effect of facial symmetry on self-face recognition**

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Previous studies (eg Brédart, 2003, Perception, 32(7), 805-811; Rhodes, 1986, Memory & Cognition, 14(3), 209-219) have shown that the representation of one's own face corresponds to a mirror-reversed image, not a normal (picture-oriented) one. The present study examined this issue with the use of morphed facial images between the normal and mirror-reversed ones. We photographed facial images of 23 male participants, then produced a morph series of a facial image (normal) into the same person's mirror-reversed one per participant. In experiment, two of the seven images of participants' own face (0%[normal], 20%, 40%, 50%, 60%, 80%, and 100%[mirror-reversed]) were presented at once, and they were asked to rate whether the left face is similar to his own face compared with the right one in terms of a five-point scale, in accordance with the Scheffé's method of paired comparison (Ura's modified method). The results showed that 100%, 80%, and 0% were significantly judged as more similar to the self-face representation than the rest of the facial images, but there was no significant difference among the three. This suggests that the symmetric property of face might affect the self-face judgment task.

◆ **Applying psychophysical reverse correlation to high dimensional natural stimuli**

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Applying psychophysical reverse correlation to high dimensional natural stimuli. Joosten ERM and Giese MA Psychophysical reverse correlation involves a trial-by-trial analysis of the relationship between stimulus noise and the observers' response. The results (classification images [1]) provide direct insight into the observers' perceptual templates. However, it remains unclear whether noisy images are similarly processed as natural images. METHODS. We developed an extension of psychophysical reverse correlation for high dimensional natural stimuli. With faces from the Cohn-Kanade database [2] stimuli were modeled by active appearance models [3] trained separately on different spatial components. This allowed us to parameterize shape variations (e.g. of the eye or mouth) by low dimensional vectors. With this classifier based approach we determined perceptual templates of different facial expressions. RESULTS AND CONCLUSION. We compared perceptual templates derived from this new approach with classical pixel-based classification images [4]. [1] Ahumada, JVis, 2:1,2002. [2] Kanade et al., Proceedings of the Fourth IEEE International Conference on Automatic Face and Gesture Recognition(FG'00),2000. [3] Cootes et al., IEEE Transactions on Pattern Analysis and Machine Intelligence,1998. [4] Sekuler et al., Curr.Biol., 14(3):5,2004.

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◆ **Conception of a psychovisual experiment for taking into account the information from different sensors images**

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To perform tasks, such as detection or recognition of objects in natural environment by day or by night, it is possible to use images acquired from different sensors: natural images, thermal images from infrared sensor or images acquired during the night with light intensifier. Our goal is to improve the efficiency of operators performing these tasks by providing a synthetic image made from different sensors that will enhance the information content of each sensor. First we have to know the image characteristics we use: edges detection and spatial frequencies are statistically analyzed. They show the differences between the image sensors. Then we have to understand which information is important for the observer, from each sensor, for a given task. To obtain this knowledge, we have developed a psychovisual experiment to discriminate vehicles, by using the method of [Gosselin, Schyns, 2001, Vision Research 41, 2261-2271]. Stimuli presented to the observers are constructed by filtering the original image at different scales and multiplied by Gaussian "bubbles" that partially obscure the signal [Lelandais, Plantier, BIOSIGNALS2013, Spain]. The results of the psychovisual experiment give the number of bubbles necessary to perform the task and to determine the useful parts of vehicles for their discrimination.

◆ **Missing the Landscape for the Artefact: Higher Saliency of Built than Natural Scene Content**

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When compared to built environments, the visual perception of natural environments engenders a more rapid and complete recovery from episodes of mental fatigue, It has been argued that underlying this effect could be a discrepancy in the saliency level between both scene categories [Kaplan, 1995, Journal of Environmental Psychology, 15(3), 169-182]. In the absence of direct support for this claim, the main objective of this study was to empirically address whether attentional capture of built scene content outweighs that of natural content. To this end, a series of four experiments were conducted in which participants detected the scene category of briefly presented natural and built scenes with backward masking. We predicted that: (1) built scenes are easier to detect than natural scenes in brief stimulus displays, and (2) built objects show greater interference with natural scene detection than vice versa. Using generalized linear mixed models, we provide convergent evidence for the contention that built content results in stronger exogenous attentional capture than natural content, both at the level of the scene and the individual object. Implications for the theories in visual perception and human-environment studies are discussed.

POSTERS : COGNITION

◆ **Gaze cueing is not modulated by spontaneous perspective taking**

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Theory of mind (ToM) refers to the attribution of mental states and perspectives to other people. Recent studies have shown that these processes can occur rapidly, involuntarily and may modulate social attention behaviors such as gaze cueing. The current work assessed this spontaneous ToM account using a series of social attention experiments where an avatar or real human conspecific either shared a participant's perspectives of a target or alternatively, had their view occluded by a physical barrier. We found that even when participants and observed individuals in displays could not see the same target, a robust social attention effect emerged (e.g., gaze cueing). The current findings suggest rapid and spontaneous perspective taking does not modulate gaze cueing effects. Implications for theories of metalizing and social attention are discussed.

◆ **Accuracy of visual estimation of the rigidity of a bouncing object**

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A locus of a moving object is a powerful cue for an estimation of the object rigidity when it bounces. Our aim of this study is to clarify how accurate our visual estimation of the object rigidity is. We presented successive animations that a circular object (0.194-degree diameter) with a coefficient of restitution bounced at a rigid floor after a drop of 15.5 degrees; observers (five undergraduates who consented to the experiments) judged which of the animations (either was the reference) included an object appearing to be more rigid. We measured thresholds of the coefficient of restitution at which the observers could detect difference between rigidities of a standard object and a test object by the staircase method. We tested at coefficients of restitution of 0.125, 0.25, 0.5, and 1.0. Accuracies of the rigidity were quite higher (more than 90 % relative to the reference's coefficient) regardless of the coefficient of restitution for most observers, and decreased with the coefficient, significantly. These results derived from ANOVA suggest that it is easier to estimate the rigidity of a harder object explicitly, than that of a softer object.

◆ **Determining Canonical Views of Objects via Electrical Brain Imaging**

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Some "canonical" object views are preferred compared to others. Psychophysical studies found that those views are recognized faster and recalled easier from memory (Blanz et al. 1999) but they activated other cognitive processes in addition to vision. We aimed at isolating the visual system's contribution

and performed two experiments while brain responses were recorded using electroencephalography with 64 channels. Experiment 1 (N=12) followed an oddball paradigm with computer-generated frequent target (a table), rare distractor (a car) and target stimuli (a chair), each in a priori determined canonical and non-canoncial views (1 stimulus/sec). Subjects were passively viewing and actively detecting the target. Experiment 2 (N=10) was a target-detection within rapid-serial visual presentation paradigm (RSVP, 10 stimuli/sec) with 40 systematically rendered views per object. Event-related potential analysis shows that i) in experiment 1 the early response (0..200 ms) distinguished between the 6 stimuli, but ii) the target-evoked P300 wave in the detection condition was indistinguishable between the two views. In experiment 2 the iii) P300 strength was affected by the target view: Apparently "canonical" views caused strongest P300 responses. Our results suggest RSVP as a paradigm to isolate the visual system's contribution in mapping canonical views from other possibly confounding cognitive processes.

◆ **Perceiving material interactions: measuring the perception of bounciness as a function of surface smoothness.**

115 K Ingvarsdóttir (Lund University Cognitive Science, Lund University, Sweden; e-mail: kristin.osk_ingvarsdottir@lucs.lu.se)

In general a bouncy object will bounce higher on a hard surface, and since hard surfaces tend to have smoother texture (tiles) than soft surfaces (carpet), one wonders whether people can use the texture information of a plane to estimate the bounciness of a colliding object. In this experiment a two-alternative forced choice task was used to measure perception of bounciness as a function of surface smoothness. Four subjects observed videos of a basketball bouncing on various surfaces. Each trial consisted of two short videos presented in a sequence, where the task was to judge which condition was bouncier. The plane's texture was altered across videos, from rough to smooth, while the bouncing was kept fixed. 3D computer graphics software was used to create 6 different surfaces, by altering the noise size of an irregular shaped Voronoi texture. The bouncing was created using a physics engine. It was expected that the perception of bounciness would increase in line with the function of smoothness, however, no difference was found between the roughest and the smoothest texture. Instead, a semi-smooth surface was perceived bouncier than the rest, which introduces a new perception criterion. The results are discussed with respect to material affordances.

◆ **Hour perception from object's surface and scene: Effects of materials and locations**

116 M Kitazaki, A Yamamoto, T Uehara, Y Tani, T Nagai, K Koida, S Nakauchi (Computer Science and Engineering, Toyohashi University of Technology, Japan; e-mail: mich@cs.tut.ac.jp)

We can estimate approximate time of day from visual information such as paintings. We aim to investigate how accurately human perceive time of day from photographs of objects and scenes, and effects of surface materials and scene locations. Photographs of a mirrored nickel and a glossy saddle leather that were identically corrugated (10x10x1.5cm) were taken at six hours (8, 10, 12, 14, 16, and 17 O'clock) at three locations (Inside of building near window, Play ground, and Outside of building on bricks) with constant exposure settings in a sunny day. We also took panorama pictures of three locations. Ten naive participants judged hours of taken pictures after 1s presentation of pictures of objects with background (Experiment 1), clipped pictures of objects only (Experiment 2), and panorama pictures (Experiment 3). Correct rates were almost identical for whole pictures of objects (35.7%; chance level 16.7%) and panoramas (35.6%), but lower for clipped object pictures (30%). Hour perception was more accurate for the nickel than the leather, and more accurate at the ground and the outside than the inside building. These results suggest that hour perception is not so accurate, and mainly based on average luminance, but also utilizing characteristics of environmental illumination.

◆ **A new theory of visuo-spatial mental imagery**

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A new theory of visuo-spatial mental imagery and a computational model instantiating it are presented. The new theory is best understood as a fleshed-out and modified version of the enactive theory of mental imagery (Thomas, Cogn Sci 23: 207-245, 1999). The theory is compared to other contemporary theories of mental imagery and evaluated against a set of critical imagery phenomena. These phenomena cover the general findings that mental imagery shows similarities to visual perception (e.g. mental scanning), yet, also shows striking differences to visual perception (e.g. mental reinterpretation). The apparent embodied nature of mental imagery (e.g. (functional) eye movements) is considered as well as the complex role of attentional processes in both mental imagery and visual perception (e.g. visual and imaginal unilateral neglect). It is argued that the new theory and its model are able to provide

explanations of these phenomena that partly go beyond the explanations offered by the contemporary theories.

◆ **Lost in Rotation: Investigating the Effects of Landmarks and Staircases on Orientation**

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Myriad studies have investigated fundamental characteristics of spatial cognition in human agents navigating through indoor environments. While translational motion has been investigated extensively, less focus has been on the effect of rotation on pedestrian movement, despite rotation being a major factor in disorientation. The process of rotating a spatial frame of reference is highly cognitively demanding because reorientation requires the user to imagine new possible perspectives and interactions with the world. We are in the early stages of developing a conceptual framework aimed at computationally analyzing the effects of rotation. The framework will provide a foundation for architects to improve their indoor layout designs and to assist users in navigating complex built environments such as public buildings. We are developing our framework based on two case studies that will be used to conduct user experiments. The influence of rotation on orientation will be measured through retrace and pointing tasks. The first case study investigates the relationship between rotations and visible landmarks, as it is known that the presence of landmarks enhances the legibility of the environment. The second case study investigates the effect of stairs through which users undergo a series of rotations in three-dimensional environments.

◆ **Effects of angle size and length ratio in angle perception**

119 J J Song, W H Jung (Department of Psychology, Chungbuk National University, Republic of Korea; e-mail: bsblgll@gmail.com)

The purpose of this study is to test the effects of angle size and length ratio on perceived size of an angle comprised two lines. In two experiments, stimuli were six angles ranging from 55°to 105°. In experiment 1, angles were compared to two conditions. One condition was consisted of two lines changed by a fixed ratio of left side lengths to right side lengths and second condition was comprised of two lines changed according to various ratios of left side lengths to right side lengths. In experiment 2, perceived angle were measured in two conditions(used in experiment 1) that were comprised of a fixed oriented or a flexible oriented line. The results showed that the angles tended to be underestimated the angle in below 80°. This result support previous studies. In contrast, perceived error of angle sizes decreased a lot in above 80°. Perceived angular sizes accuracy was not instrumentally affected by length ratio. These results suggest that angle detectors may exist and detect better obtuse angles than acute angles.
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◆ **Testing the order-theoretic similariy model and making perceived similarity explicit with**

120 **Formal Concept Analysis**

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Similarity ratings are a widely used tool for the assessment of high-level perceptual similarity. Several approaches to conceptualizing similarity exist. We are concerned with the featural approach which was developed by [Tversky, 1977, Psychological Review 84:327-352] and mathematically formalized in [Lengnink, 1996, PhD Dissertation, TU Darmstadt]. This formalization posits a partial order between pairs of objects (stimuli) as the fundamental mathematical structure of similarity, traditional similarity measures (e.g. Russell-Rao, Jaccard etc.) are conceived as order-preserving mappings from the partial order between pairs into the (real) numbers. This approach preserves the main structural features of Tversky's model, and makes additional predictions about the (non-)comparability of similarity between pairs of objects. We tested these predictions experimentally: a) subjects rated the similarity between natural images on a 7-point Likert scale, and b) they ordered pairs of images by their perceived similarity. We find that the ordering predictions of ratings are well preserved (>85%). One drawback of similarity ratings is that they provide only an implicit measure of "relatedness". We employ theoretical framework of Formal Concept Analysis [Ganter & Wille, 1996, Formal Concept Analysis, Springer, New York] to make the relationships explicit as concept lattices, which generalizes traditional approaches based on hierarchical clustering.

◆ **Spaced practise shows similar patterns of improvement for visual acuity and vocabulary**
121 **learning**

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Temporally distributed ("spaced") learning can be twice as efficient as massed learning. This "spacing effect" occurs in humans of different ages and in animals, with different learning materials and even with visual acuity test performance. We tested the dependence of both visual acuity performance and vocabulary learning on spacing interval duration. Six groups of participants performed visual acuity tests (gap detection) and learned Japanese -German vocabulary (word associations) with different spacing intervals between practise units (from 7 min to 24 h). Three final tests were executed at "retention intervals" of one, seven and 28 days after the last practice unit. Spacing effects occurred for both tasks with maxima at 20 min and 12 h: In the 12-h-spacing group the gain of visual acuity and about 92 % of the learned words were retained after four weeks. In the 24-h-spacing group, in contrast, the visual acuity gain dropped to zero and more than 60 % of the learned words were forgotten. The very similar patterns of results across the very different practice domains indicate similar underlying mechanisms. Further, the nonlinearity pattern of the spacing effect point to separate steps to establishing long-term memory.

◆ **Eye Movement Patterns in Memorizing Foreign Words**
122

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As it was demonstrated by Višnja Pavicic Takac [2008, Vocabulary learning strategies and foreign language acquisition, New York: Multilingual Matters], people use different strategies to memorize foreign words, which vary in correctness of reproduction. This report examines strategies of memorizing unfamiliar words of foreign language, which can be revealed through patterns of eye movements. Words of a foreign language and their translation (one pair at a time) were visually presented to the subjects, who later had to reproduce these words. Parameters of eye movements were registered from the moment a testee started looking at the screen. The correctness of word reproduction was also counted up. With the help of cluster analysis (based on the number of fixations on the words of the native language and on the quantity of regressive eye-movements) groups with different eye movement patterns were identified, which proved to have distinctions in correctness of reproduction ($F(1, 101) = 4{,}05$, $p=0{,}047$). In this case, the more the duration and the number of fixations was on the words of the native language, the better was memorizing. The received data can be used in design of textbooks on foreign languages.

◆ **Influence of Syntactic Information on Eye Movement Control in Reading**
123

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We will examine to what extend syntactic prediction could influence eye movement behaviour in reading. We will report there experiments where the morphology of the upcoming word was predicted from previous sentence context. First two experiments were in English and we tested whether the use sentence initial information (indicating an upcoming plural noun) would influence parafoveal processing of that noun (e.g. these/this fascinating toy/toys). We found that the readers more likely to skip the noun if its morphological information was predicted. Indicating that the reader process morphological information parafoveally and these syntactic expectations influenced the control of saccade movements. We also examined parafoveal processing of morphological information in Turkish where the morphology of the upcoming word was predicted from previous sentence context. In Turkish negation is marked with a specific morpheme at the verb. By manipulating sentence initial information we created an expectation for a negative verb. If the readers are more likely to access morphological information from the parafovea when this information is predicted, then the skipping rates should be higher. We will discuss the implications of these results for lexical access in reading models.

◆ **Luminance and contrast affect binocular coordination in reading**
124

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In studies of binocular coordination in reading, various vergence disparities were reported. Nuthmann and Kliegl (2009) observed more crossed, whereas Liversedge et al. (2006) observed more uncrossed disparaties. Several potential reasons for these differences have been investigated in the last years (e.g. Shillcock, 2010, Kirkby et al., 2013, Nyström, 2013). One still open question is whether the luminance

of the screen produces variations in binocular coordination. In an earlier experiment we showed vergence disparities changing with the polarity. In order to examine effects of the font versus the background, we replicated this study and additionally presented the text either with dark letter or with bright letters on the same grey background. Before, the participant's eyes were calibrated with black-white Gabors on a grey background. The data replicated the former findings and show that the background color changes vergence disparity.

◆ **Seeing is knowing? Visual word recognition with and without Dyslexia**

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In this study Event Related Potentials (ERPs) technique was used to investigate whether higher order (phonological and semantic) stages of visual word recognition take place simultaneously or following processing in earlier visual features stages. Thirteen dyslexic (4 female) and 15 non-dyslexic (6 female) native English speaking young adults were tested in visual orthographic (words and pseudohomophones, W and PH1) and phonological (pseudowords and pseudohomophones, PW and PH2) lexical decision tasks. Reaction times (RTs) showed the following latency across 4 conditions: W<PH1<PH2<PW. Analysis of occipito-parietal ERP activation revealed the amplitude of P1, N1, P2, N2 and P3 components was significantly larger in the first compared to the second task in controls but not dyslexics. The latency of these components was longer in dyslexics. The amplitude of N2 and P3 components was larger and their latency longer in PH2 compared to PW condition in controls only. Overall results suggest that low level visual task required less effort than phonological task hence larger amplitude of ERPs in latter, whereas the larger amplitude of N2 and P3 in PH2 compared to PW condition in controls showed higher order processing of phonology and semantics takes place at around and no earlier than 250-300ms.

◆ **A Contrast Energy Model for Relative Numerosity Discrimination**

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It has been suggested that numerosity is an elementary quality of perception, similar to colour. The mechanism for relative numerosity discrimination has proved elusive, in part because of the inevitable correlations between number, overall pattern size, density and size of the elements, all of which affect discrimination thresholds when they are varied. Here we suggest that relative numerosity is a type of texture discrimination, and provide a model of relative numerosity discrimination which computes the energy in two spatial frequency-tuned bandpass filters against which data can be tested and compare its ability to that of human observers. To test the model we measured the ability of human observers to distinguish patterns differing in numerosity and blur using a temporal 2AFC design in which a standard stimulus containing 64 dots in an equally sized area but with irregular shape was presented on each trial along with a test stimulus containing either fewer or more dots. Like some human observers, this mechanism finds it harder to discriminate relative numerosity in two patterns with different degrees of blur, but it still outpaces the human. We propose energy discrimination as a benchmark model against which more complex models and new data can be tested.

◆ **Numerosity is represented spatially: evidence from a 'SNARC' task**

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A central finding within numerical cognition is that symbolic numbers (i.e. Arabic numerals) are represented spatially with smaller numbers associated with the left side of space and larger numbers with the right [e.g. Fischer et al, 2003, Nature Neuroscience, 6(6), 555-556]. This study investigated whether numerosity is also represented spatially. Participants judged whether a briefly presented dot cloud stimulus contained more or less dots than a reference dot cloud. It was predicted that dot clouds with less (or more) dots than the reference would be categorized more quickly when 'less' responses were assigned to the left hand and 'more' responses to the right hand compared to the other way around (the so-called 'SNARC' effect - Spatial Numerical Association of Response Codes). This effect was observed, but it may have been because numerosity per se is represented spatially, or because total dot surface area - which co-varied with numerosity in this experiment– is represented spatially. To distinguish between these two possibilities, a follow-up experiment was conducted in which total dot

surface area was held constant as numerosity increased. The effect remained, indicating that numerosity is represented spatially.

◆ **The role of segmentation in encoding numerosity**

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Humans have a clear sense of the number of elements in a display. However, how segmentation affects numerosity is not well understood. To study segregation we used a sequential 2-AFC task where subjects were presented with a yellow and blue dot display in the first interval, then asked to judge whether there were more or fewer green dots displayed in the second interval. Subjects were cued either before or after the first stimulus whether to base their response on the number of yellow, blue or total dots. We tested 8 different blue/yellow colour ratios and 4 different total dot numerosity/densities. The results show that when judging the total number of dots, subjects accurately compare magnitudes, regardless of cue condition. However, when pre-cued for an individual colour, subjects substantially overestimated displays with large distracter ratios. In contrast, when post-cued, subjects underestimated individual features quantities up to 30%, with the maximum underestimation occurring for equal numbers of target and distracter. Overall the results suggest that numerosity displays are automatically processed as a single grouped display, with multiple features interfering in the estimation of numerosity, in a way that depends on whether subjects are required to segment the display visually or from memory.

◆ **Eye Movements Influence the Magnitude of Randomly Generated Numbers**

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Theories of embodied cognition share the notion that the body and its sensory and motor systems play a fundamental role in cognition. Consistent with this view, it has recently been demonstrated [Loetscher et al, 2010, Current Biology, 20(6), R264-R265] that the magnitude of numbers generated by participants in a random number generation task could be predicted – prior to their being spoken - by tracking their eye movements. Specifically, leftward eye movements predicted smaller numbers and rightward eye movements predicted larger numbers. Remarkably, the size of the shift in eye position also predicted the size of the shift in numerical magnitude. An unresolved issue, however, is whether there is a causal link between eye movements and the magnitude of generated numbers. To address this, and to control for a possible mediating influence of head movements, three experiments were conducted. Participants made alternating left and right eye movements (Experiment 1), head movements (Experiment 2) or head and eye movements together (Experiment 3) whilst generating numbers at random, from 1 to 30 inclusive. Number magnitude was influenced by eye movements. The present study offers support for the embodied cognition framework, demonstrating that low-level physical manipulations of the body can influence abstract cognition.

◆ **Sight-reading in skilled pianists: Eye-hand span is independent of practice but associated with the musicians' cognitive abilities**

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Sight-reading is a skill required by musicians when they perform an unknown composition. It demands sequential anticipatory fixation of notes immediately followed by motor performance. The distance between eye and hand position is called the eye-hand span (EHS). The aim of our study was to investigate the influence of practice, playing tempo and complexity of the music on the size of the EHS, as well as its relation to performance and cognitive skills as measured by shape recognition, working memory and mental speed tasks. Nine pianists of the Hanover University of Music and Drama participated. We found that a practice phase of 30 minutes of a 3 minute composition did not affect the EHS but that the EHS significantly increased with faster playing tempo and for easier parts of the music. Furthermore the EHS was significantly correlated with quality of performance after practice and with mental speed skills. We conclude that the EHS is affected by tempo and structure of the music. Moreover, the EHS is associated with the musician's cognitive abilities and playing skills. Hence, the EHS seems to be a characteristic of each musician developed over years of practice and independent of a short practice phase.

◆ **Fluency needs uncertainty**

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Processing fluency, that is to say, the ease with which a stimulus is processed, has strong influences on preference. The easier a stimulus is to process, the higher the preference judgment. This effect has been observed for line drawings, simple patterns, or words. In contrast, some studies using more complex stimuli, such as faces or artworks, fail to find a relation between fluency and preference. We suggest that these divergent findings owe to different degrees of uncertainty in the experimental settings. Uncertainty can be manipulated, for example, by hampering perception or varying the subjectivity of rating dimensions. In our experiments we studied the effect of perceptual fluency on different stimulus categories and rating dimensions. For simple line drawings, results suggest that fluency effects require a certain amount of uncertainty due to both stimulus perceptibility and rating dimension. Specifically, fluency effects were observed for hard to perceive stimuli and only when using a more subjective rating. This indicates that uncertainty might be a prerequisite for the fluency effect. Furthermore these results can explain why a fluency effect was not found in certain studies that used more complex material than line drawings or simple patterns.

◆ **When what we need influences what we see**

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Recent reports question the evidence for an 'embodied' perception of geographical slant. While Proffitt (2006, 2011) proposes that slant perception is malleable to fit with an individuals' available energy resources, Durgin and colleagues (2010, 2012) argue evidence for this model can be put down to artifacts of experimental design. Schnall et al. (2010) previously showed that after consuming a sugary drink, explicit estimates of hill slant were reduced in line with increased energy resources, a finding also questioned by Durgin (2012). New approaches are required to resolve this debate. Here, two experiments used a 'post-choice paradigm,' which diminished the influence of experimental demands. Participants (n=414) unknowingly selected their own experimental grouping by choosing from a selection of fruit and drink items differing in energy content either before (exp. 1), or after (exp. 2), providing perceptual judgements of slant for a large staircase (6.45m, 23.7°). Results showed participants opting for items more likely to replenish their energy stores provided steeper slant estimates, indicating perception was scaled in line with energy needs. Effects of choice remained robust when controlling for demographics, and perceived climbing effort, suggestive of a process whereby implicit knowledge of available energy resources manifests in explicit perception of steepness.

◆ **Uncertainty Effect on Task Irrelevant Learning**

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Task-irrelevant learning (TIL) refers to the phenomenon where stimulus features of a subject's task that are presented at relevant point in times are learned, even in the absence of attention to these stimuli. We present experiments that test the effect of uncertainty on TIL. The idea is that it is at times of maximum uncertainty in which learning is most desirable. We conducted two experiments to study the effect of the two forms of uncertainty: expected and unexpected uncertainty (Yu & Dayan, 2005) and compare TIL under uncertainty and under no uncertainty. We used the fast-TIPL paradigm (Leclercq & Seitz, 2011) where subjects perform an RSVP task in which target can be preceded by a cue. Different conditions of cueing were used to test our hypothesis. Our results indicated a larger TIL effect under uncertainty than under no uncerntainty without difference between expected and unexpected uncertainty. The results indicated that the effect of uncertainty on TIL exists on women but not in men. In men, an equivalent TIL was observed under no uncertainty and expected uncertainty, whereas in women, according to previous results (Leclercq & Seitz, 2012), no TIL was observed under no uncertainty, but was observed under the uncertainty conditions.

◆ **Impact of nonconsciously perceived information on decisions**

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Priming refers to the process of activating parts of particular representations of associations in memory just before carrying out an action or task. So priming can be seen as an effective cognitive mechanism that activates a user's previously stored schema and increases the accessibility of existing information in memory. Even incidental exposure to a stimulus can activate associated mental constructs and cause

people to behave in a manner which is linked up with the activated construct. In some cases, this impact on behavior has been observed even when subjects are not aware of having been exposed to the information earlier. This all holds particularly true for existing representations. However, a salient question arises: What happens, if a subject is exposed to a completely novel stimulus without any existing representation in its memory and without knowledge of being exposed? In other words, the exposure happens nonconsciously. Does this nonconscious encounter lead to a new implicit memory representation which also impacts on subsequent decisions? To take a closer look at that salient issue, we conducted an experiment which reveals a significant difference between control and experimental group.

◆ **Pupil dilation reflects the temporal evolution and content of a perceptual decision**

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Pupil dilation at constant illumination has long been used as an index of mental effort and arousal. More recently, pupil dilation has been linked to perceptual decision-making, though the exact nature of this link has remained unknown. Here, we asked (i) whether decision-related pupil dilation is driven only by the final commitment to a choice, or also by the preceding evidence integration process; and (ii) whether its amplitude reflects the final choice, or the correctness of the choice. We measured pupil dilation in four subjects (each 2400 trials) during a yes-no visual contrast detection task (free response paradigm), in which the target pattern was embedded in dynamic noise, provoking prolonged temporal integration (range of median RT: 1439-2440 ms). Linear system analysis of the pupil diameter time course revealed significant transient components at stimulus onset and choice, and a significant ramping component during decision formation. The overall amplitude of pupil dilation was bigger for hits and false alarms than for misses and correct rejects. The pattern of results replicates in a bigger sample of subjects. Our results suggest that the autonomic systems mediating pupil dilation are continuously driven by ongoing decision processes and informed about the contents of decision outcomes.

◆ **'Not everything was bad' – Visual efficacy of East and West German 'Ampelmännchen' traffic signs probed through cognitive conflict**

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In post-unification Germany, lingering conflicts between East and West Germans found some unusual outlets, including a debate of the relative superiority of East and West German 'Ampelmännchen' pedestrian traffic signs. In this study, we probed the visual efficacy of East and West German Ampelmännchen signs with a Stroop-like conflict task. Twenty participants were asked to respond as quickly as possible to the shape or color of East or West German Ampelmännchen signs which were either presented in their normal version, with congruent shape and color information, or in a version with incongruent shape and color. Different sizes of colored spaces in these signs were controlled through further benchmark stimuli. We found that the distinctive East German man-with-hat figures were more resistant to conflicting information, and in turn produced greater interference when used as distractors. These findings demonstrate Stroop-like effects for real-life objects, such as traffic signs, and underline the practical utility of an East German icon.

◆ **An Evaluation of the Flash Pattern of LED Warning Lights for Improving Distinctness**

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In recent years, the number of emergency vehicles equipped with light-emitting diode (LED) warning lights has increased. The purpose of this study is to investigate the optimal flash patterns of LED warning lights and to improve the visibility of emergency vehicles. We are able to control flash patterns of LED lights via computer. We used various flash patterns with a combination of lighting time (ON time 11, 22, 33, 44, 55, 66, 99, and 132 msec) and no-lighting time (OFF time 11, 22, 33, 44, 55, 66, 99, and 132 msec), and measured the reaction time (i.e. 'distinctness') of LED warning lights under the conditions of varying ages (a young group and an old group), intensity of illumination against a background (bright 330 lux, or dark 28 lux), and luminance of LED warning lights (bright 220 cd/m2, or dark 26 cd/m2) by psychological experiments. We found that (1) OFF time affected the reaction time (distinctness), (2) the

flash pattern of 33-msec OFF time provided optimal visibility regardless of ambient conditions in any brightness, and (3) reaction time was not affected by age.

POSTERS : DEVELOPMENT AND AGEING

◆ **No evidence for childhood development in viewpoint invariant face encoding**

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Performance on face recognition tasks improves across childhood not reaching adult levels until adolescence. Debate surrounds the source of this development with recent reviews suggesting underlying face processing mechanisms are mature early in childhood and that the improvement seen on recognition tasks instead results from general cognitive/perceptual development. One face processing mechanism which has been argued to develop slowly is the ability to encode faces in a view invariant manner (i.e., allowing recognition across changes in viewpoint). However previous studies have not controlled for general cognitive factors. In the present study 7-8 year-olds and adults performed a recognition memory task with two study-test viewpoint conditions: same-view (study front view, test front view); change-view (study front view, test three-quarter view). To allow quantitative comparison between children and adults, performance in the same-view condition was matched across the groups by reducing the learning set size for children. Results showed poorer memory in the change-view than the same-view condition in both adults and children. Importantly there was no quantitative difference between children and adults in the size of decrement in memory performance resulting from a change in viewpoint. This finding adds to growing evidence that face processing mechanisms are mature in early childhood.

◆ **Visual Bandwidths for Face Orientation Decrease During Early Development**

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Accuracy in matching facial identities between frontal and side views declines during healthy aging (Habak et al., 2008, Vision Research, 48, 9-15). Evidence from behavioural experiments and neural models suggests that this decline reflects a broadening of cortical bandwidths for face orientation (Wilson et al., 2011, Vision Research, 51, 160-194). Before age 10, children are less accurate than adults in matching facial identities across face views (Mondloch et al., 2004, Journal of Experimental Child Psychology, 86, 67-84). We investigated whether this age difference could reflect broader bandwidths for face orientation in children. Adults (n=20) and 8-year-olds (n=18) were adapted to a frontal face view or a left/right side view. A test face at or near the frontal orientation was then briefly presented. Participants pressed a button to indicate whether the test face was rotated to the left or right. Sensitivity to face orientation was lower and aftereffects following left/right adaptation were larger in 8-year-olds than adults. A neural model shows that these differences can be modelled by broader bandwidths for face orientation and higher internal noise in 8-year-olds. Hence, improvements in children's ability to match facial identities across face views may reflect a narrowing of cortical bandwidths for face orientation.

◆ **What limits global motion processing in development? An equivalent noise approach**

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The development of motion processing is a critical aspect of visual development, allowing children to interact with moving objects and move around in a dynamic environment. Despite this importance, global motion processing abilities, as assessed with the motion coherence paradigm, develop reasonably late, reaching adult-like levels only by mid-to-late childhood [Gunn et al., 2002, Neuroreport, 13(6), 843-847]. However, the reasons underlying this protracted developmental trajectory are not yet fully understood. In this study, we sought to determine whether performance in childhood is limited by sensitivity to local motion direction (internal noise) and/or the ability to pool estimates at the global level (sampling efficiency). To this end, we presented equivalent noise direction discrimination and motion coherence paradigms tasks at both slow (1.5 deg/sec) and fast (6 deg/sec) stimulus speeds to 5-, 7-, 9-and 11-year-olds and adults. Our data suggest that improved motion coherence thresholds through childhood are accompanied by reductions in internal noise and gains in sampling efficiency.

Developmental improvements in global motion perception therefore appear to be driven by changes in both local and global processes.

◆ **Dynamic changes in infant visual preference for optic flows just before the onset of**
141 **voluntary locomotion: a longitudinal study**

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Perception of radial optic flow takes a critical role to perceive and control the direction of locomotion. We longitudinally investigated developmental interaction between the perception of radial expansion/contraction flows and the locomotor ability in infancy. Infants (N=20) were tested for 4 consecutive months, from 3 months before the month in which locomotion emerged. The first month in which each infant showed voluntary locomotion was defined as '0 month'. The three months before '0 month' were defined as '-3', '-2', and '-1 months'. Each infant's visual preferences and locomotor ability were assessed every month during that period. Results indicated that the preference for contraction (but not for expansion) suddenly decreased just before the onset of the locomotor ability. This suggests that the drastic change in visual preference to contraction flow precedes to the acquisition of locomotor ability. The potential role of the observed visual development in emergence of motor abilities such as locomotion will be discussed.

◆ **Children's perceptual capacity to detect collision impact**
142

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Two experiments investigated children's perceptual capacity to detect potential collision impacts. Children from 4 to12 years of age participated as observers in the study. In Experiment 1, displays depicted either a small car or a large truck approaching the observer against a road-scene background, producing a local perturbation in the visual field. In Experiment 2 displays depicted the observer's own movement toward obstacles (a global perturbation of the visual field). Simulated approaches were created following the tau-dot hypothesis in which, when tau-dot >=-0.5, approaches result in safe stops without collision; but when tau-dot < -0.5, approaches result in collisions with impact. Predefined tau-dot values remained constant throughout each simulated approach. Results demonstrated that 4-6 year olds performed poorly compared with 7-12 year olds. Nevertheless, even the 4 year olds performed consistently with that predicted by the tau-dot hypothesis in Experiment 1 but their performance deteriorated to chance level in Experiment 2. Current child pedestrian safety education focuses on facilitating children's abilities to cross streets safely by enhancing their sensitivity to optical variables specifying time-to-contact. This research supports developing children's perceptual capacity to detect potential collision impact as part of these training programs.

◆ **The effect of biomechanical properties of motion on 6-month-old infants' and adults'**
143 **perception of goal directed grasping actions**

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The current study investigated whether the biomechanical properties of motion are relevant for 6-month-old infants and adults processing of human goal-directed actions. Participants observed a biomechanically possible goal-directed action and a similar action executed in a biomechanically impossible manner. Their gaze was recorded by means of an eye-tracker. Both adults' and infants' looking time to the grasping hand was longer in the impossible than in the possible condition, demonstrating that participants discriminated between them. Moreover, participants manifested predictive gazes (i.e. gazes reached the goal before the arrival of the agent's hand) in both possible and impossible conditions, suggesting that they coded both actions as goal directed. However, infants who were presented first with the possible grasping action made more predictive gazes in the possible condition, than in the following impossible one. This suggests that information about the anatomical plausibility of the observed action is relevant for the understanding of that action. Importantly, the observation of the biomechanically impossible grasp triggered in adults an increase in pupil diameter, suggesting a higher emotional arousal.

◆ **Anti-saccade performance in young and old: What juvenile and elderly have in common**

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The ability to inhibit reflexive behavior to achieve long-term goals is associated with cognitive control and modulated by age. Especially elderly people suffer from impaired cognitive control and oculomotor behavior. We analyzed the performance of teenagers, young adults and elderly people (age 15-93 years, n=354) in the anti-saccade paradigm. There, subjects should move their eyes in the opposite direction to a visual stimulus ("anti-saccade"). Sometimes, subjects succumb to their reflexive behavior and look at the target ("pro-saccade"). The frequency of pro-saccades ("error rate") is an ideal measure for cognitive control. Paralleling earlier reports [1], shortest pro-saccadic reaction times (pro-SRTs) were found in teenagers and young adults, whereas elderly people showed longer pro-SRTs. Anti-SRTs were shortest only in young adults. Surprisingly, anti-SRTs of teenagers were more similar to those of elderly people. The same age dependency showed up in the error rates. The analysis of saccadic peak velocities revealed no influence of age. Increased anti-SRTs and error rates in teenagers may be attributed to delayed maturation of the frontal lobes [1]. Overall increased SRTs and elevated error rates in elderly people may be a good indicator for an age-related decline in cognitive control. [1] Munoz et al, 1998, Experimental Brain Research, 121, 391-400.

◆ **The effect of normal development and aging on low-level visual field asymmetries**

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It is well known that aging affects contrast sensitivity (CS) but its relation with changes in visual field asymmetries is still poorly understood. We have previously documented low-level interhemispheric (left/right), superior/inferior and retinal (nasal/temporal) anisotropies based on psychophysical/structural measurements. Our main goal was to explore these asymmetries in normal development using achromatic CS tasks, which probe distinct spatiotemporal frequency channels. Monocular CS was measured using intermediate (ISF: 3.5 cycles per degree (cpd) and 0 Hz; 303 eyes; 7-72 years, sampled in five age groups) and low spatial frequency tasks (LSF: 0.25 cpd undergoing 25 Hz counterphase flicker; 311 eyes; 10-83 years). Using ISF, left/right asymmetry was found only for young adults ($p=0.002$) and superior/inferior asymmetry was not present in children but increased with aging, with enhancement of inferior hemifield advantage ($p<0.001$). Retinal asymmetries were present across age groups with nasal hemifield advantage. Concerning LSF, children and older subjects did not exhibit cortical hemifield asymmetries; adolescents/adults showed only retinal asymmetries ($p=0.005$). We conclude that visual asymmetries with a direct ecological meaning (up/down at the highest spatial frequency) emerge during development and aging whereas retinal forms of anisotropy tend to stabilize or decline, while interhemispheric asymmetries are more specific to young adults.

◆ **Step rate dominance in estimation of the maximum gait speed for elderly women**

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The present study examined how accurately elderly women could estimate their own maximum walking speed (WSmax). Ten subjects observed apparent motions of footprints that represent human gait patterns. Footprints motions consisted of the four different gait patterns combined with step length (SL) and step rate (SR): actual combination of each subject gait, it reversed combination, different SR with constant SL, and different SL with constant SR. Footprints walking was projected onto a screen on the floor in the real scale. In each of the four conditions, the speeds of footprints walking randomly varied between ±20% of the subject's WSmax. The subjects determined whether she could maintain the speed of the footprints walking. Constant error and sensitivity in the estimation of WSmax were calculated from the best fitting logistic functions to subject's judgments. The mean constant error was 3.6±5.7% of the subject's WSmax. The mean sensitivity for the constant SL condition was significantly smaller than those for the other conditions. These results suggest that elderly women could accurately estimate their WSmax or overestimated it to some extent. It is likely that the aged people may be more sensitive to the changes of SR in perception of the maximum walking boundary.

◆ **Ageing reduces sensitivity to timing mismatches in the perception of human motion**

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Timing of events conveys important information about causality [Michotte, 1963, The perception of causality, New York, Basic Books]. We examined whether the sensitivity to timing in human motion changes with ageing. Stimuli consisted of computer animations of one character (pusher) approaching and pushing another character (target) on the back, causing him to step forward. Timing mismatches were introduced at the point of contact to create animations where the target either anticipated or delayed his reaction [Hoyet et al., 2012, ACM T Graphic, 31(4)]. In Experiment 1, younger and older participants judged whether the target's reaction was early or late. The perceived correct timing was biased towards early reactions in both groups, but the bias was significantly greater in older participants, who also showed poorer sensitivity to timing. In Experiment 2, participants judged which of two animations had the correct timing for animations with no sound, a sound at or before the time of contact. Whereas younger participants detected reliably timing mismatches as short as 100ms, older participants required more than 200ms mismatch to do so. Presentation of the sound affected only the perceived correct timing, not the sensitivity. These results have important implications for perception and mobility in older age.

◆ **Do hands alter age perception from the face?**

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Although hand appearance seems to be of some importance in social relations, perception studies concerning hands are rare. Here we investigated whether it is possible to estimate the age of a person from her hand, and whether hands can modify facial age estimation. Photographs of hands and faces of 40 Caucasian women from 20 to 69 years of age were shown to 64 Caucasian female participants of the same age range. First, the participants were asked to estimate the age of the women from their face only, and then from their hand only. Three months later, the same participants estimated the age of the women from their face and their hand presented simultaneously. Participants were able to estimate the age from the hand although they were more accurate when estimating the age from the face. When the face and the hand were presented simultaneously, the perceived age was more accurate than the perceived age from the face, but there was no significant difference. Although the face seems to be the most important cue for age estimation, these results suggest that the hands also play a role, decreasing or increasing the perceived age of the person.

◆ **Dynamic information benefits unfamiliar face perception in older adults**

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Studies using static images have reported poorer unfamiliar face perception in older (OA) than younger adults (YA). However, the role of facial motion in unfamiliar face perception with ageing remains unclear. Here, OA and YA learned faces either dynamically (video) or from a sequence of static images, with rigid (head rotation) or non-rigid (facial expression) changes. Immediately following learning, participants matched a static test image to the learned face. Test images varied by viewpoint (Experiment1); expression (Experiment2) and were familiar or novel. Although OA face matching performance was worse than YA, learning a face through rigid motion benefited matching performance in OA, particularly for novel viewpoints. Conversely, when non-rigid changes were learned, we found no difference in face matching performance across the dynamically or statically presented faces for OA and YA (although performance was relatively poor for OA group). Results from Experiment3 revealed that non-rigid motion interfered with the perception of inverted faces, suggesting that the ability to use dynamic face information for the purpose of recognition reflects a motion encoding which is specific to faces. Our results suggest that as we age face perception may benefit from cue combination, specifically spatial and dynamic, particularly when generalising across unfamiliar views.

◆ **Effect of color and color-word cues on the following color-word discrimination task: aging**
150 **study**

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In the previous study we examined age factors in effects of exposure to color and color-word cues upon later color discrimination task. As a result, the old participants were less affected by the cues, whereas the young participants' response seemed to be inhibited by color cue information. For further investigation, we conducted a color-word discrimination experiment under the equivalent setting. The target was color-word of "red" or "green" (in Japanese), preceded by a cue with 4 kinds of color, color-word, congruent colored word, and conflict colored word. Young and old participants were instructed to discriminate the target with ignoring the cue. Not surprisingly the old participants generally responded slower than the young. There was, however, an asymmetrical change in effect of the cues from that found in the color discrimination experiment between the participant groups. Namely, the old participants' response was inhibited by the no word cue in the present study, whereas the young participants showed less effect of the cues. This result could not be merely attributed to differences in the rate of processing and/or responsiveness to relevant cue information. Instead it suggests that a qualitative difference in interaction of word and color processing arises in aging.

◆ **Age-related behavioural and neural differences in multisensory processing**
151

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Ageing affects how we combine information across the senses. Recently we showed that older adults are more susceptible to the sound-induced flash illusion than younger adults. Here, we examine the timecourse and the neural correlates of the fission and fusion variants of this illusion in young and old adults. The fission illusion refers to instances where two auditory beeps cause one flash to be perceived as two. Young participants experienced fission on a smaller proportion of trials and only when the beeps were separated by short, but not longer stimulus onset asynchronies (SOAs). Older adults experienced fission more often than young participants at short SOAs, but showed no recovery with increasing SOAs. The fusion illusion refers to instances where two flashes accompanied by one beep appears as one flash. Again, young adults showed a significant illusory effect at the shortest SOA, but recovered quickly as this interval increased. Older adults were again more susceptible to this illusion overall, however, the timecourse of this effect more closely resembled that of young adults. We examine the neural correlates of both illusions with fMRI by comparing BOLD activation in early visual areas for trials where identical stimuli lead to different percepts.

◆ **The Role of Environment Familiarity on Spatial Memory for Novel Objects: An Ageing**
152 **Study**

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We investigated whether familiarity with an environment affected performance on egocentric and allocentric spatial processing across older and younger adults. Although few studies have considered the role of familiar routes on spatial memory, some evidence suggests that older adults have preserved spatial recognition for familiar environments learned in the remote past [Rosenbaum et al., 2012, Frontiers in Aging Neuroscience, 4 (25), 1-10]. We created a virtual scene of a local environment through which participants passively navigated. Fifteen young (m=23 years) and 15 older (m=69 years) participants first provided familiarity ratings of the real environment. They were then shown two routes (one 'familiar' and one 'unfamiliar') in which novel landmarks were embedded. Following learning, participants' spatial memory was tested using 3 separate tasks: a landmark recognition test, a direction judgement task (egocentric processing), and a proximity judgement task (allocentric processing). We found poorer overall performance for the older than younger adults across all spatial tasks, although allocentric memory was worse for older adults. Environment familiarity was associated with improved landmark recognition and allocentric processing in older adults. These results suggest an important facilitatory role of environment familiarity on spatial memory for object locations in older adults

◆ **Verification of the validity of the visual N-back task as a cognitive stress test for clinical diagnosis using fMRI**

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It has been pointed out that the BOLD signal is augmented depending on aging (Aizenstein et al., 2004). However, the pattern and extent of age-related change depends on the task and its difficulty. In this study, we attempted to evaluate the validity of visual N-back task (vNb) as a cognitive stress test for clinical diagnosis using fMRI. Twenty healthy normal young and 20 healthy normal elderly volunteers participated in this study. Experiment conditions were task difficulty (N = 1, 2, 3). Functional data were obtained using a T2* weighted gradient recalled echo EPI sequence (TR = 3000 ms, TE = 30 ms, 39 axial slices, 3 mm thick, FOV = 19.2 cm) on a 3T MRI scanner. The functional images were realigned, normalized and analyzed by SPM8. In the visual cortex ([BA] 17, 18, 19) and dorsolateral prefrontal cortex ([BA] 45, 46), significant activations were observed in all conditions ($p < 0.001$, uncorrected, RFX). These brain activations depending on the difficulty of vNb were different between the two age groups. These results showed that vNb may be applied for clinical diagnosis to detect the influence of aging on both cognitive domain of visuo-spacial recognition and learning objectively.

◆ **Ageing differentially affects processing of different conflict types**

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There is converging evidence that conflict processing of different conflict types relies on distinct neural mechanisms. However, it is still under debate how neural processing of different conflict types is affected by ageing. In this study, a combined Flanker and Simon task was performed by young and elderly participants during fMRI recording. With regard to behavioral performance, data analysis revealed larger Simon effects in elderly while Flanker task effects did not differ between both groups. fMRI data demonstrated distinct neural networks being involved in conflict processing. Flanker conflict processing was associated with additional recruitment of postcentral gyrus in older participants. In contrast, Simon conflict elicited activation of inferior frontal gyrus and inferior parietal lobule specific to elderly individuals. These findings indicate a differential effect on distinct conflict types in ageing.

◆ **Neural markers of individual and age differences in TVA attention capacity parameters**

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The 'Theory of Visual Attention' quantifies an interindividual's capacity of attentional resources in parameters visual processing speed C and vSTM storage capacity K. Distinct neural markers of interindividual differences in these functions were identified by combining TVA-based assessment with neurophysiology: Posterior N1 amplitudes were lower for participants with higher relative to lower processing speed and correlated with individual C-values and CDA was larger for participants with higher relative to lower storage capacity and correlated with individual K-values. When the approach was extended to investigate neural underpinnings of age-related changes in attentional capacities, the ERP markers of individual differences in processing speed and storage capacity were validated also in the older group. Furthermore, additional components were related to performance exclusively in elderly: Anterior N1 amplitudes were reduced for slower older (relative to younger and faster older) participants and correlated with C-values only in the older group. High-storage capacity older (relative to younger and low-storage capacity older participants) obtained a stronger right-central positivity, which correlated with K-values only in the older group. Our findings specify age-related reorganization of attentional brain networks underlying decline and reserve and furthermore show that the distinctiveness of both functions is preserved (or even increased) in older age.

POSTERS : BRAIN RHYTHMS

◆ 156 **The phase of pre-stimulus theta oscillations gates cortical information flow and predicts perception performance**

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Contrary to the subjective impression that visual information flows continuously from our sensory channels, recent evidence suggests that the sensitivity for visual stimuli fluctuates periodically. The neural mechanisms underlying this perceptual sampling are yet unknown. We here tested the hypothesis that the perceptual sampling rhythm is mediated by on-going brain oscillations which gate the transfer and integration of information between higher and lower level visual processing regions. Human participants performed a contour detection task while brain activity was recorded simultaneously with EEG and fMRI. The results obtained from EEG-informed fMRI analysis and dynamic causal modelling demonstrate that the phase of an on-going 7 Hz oscillation prior to stimulus onset modulates perceptual performance and the bidirectional flow of information between the medial occipital cortex (putative V4) and right intraparietal sulcus. These findings suggest that brain oscillations gate visual perception by providing transient time windows for long-distance cortical information transfer.

◆ 157 **An EEG/fMRI study of gamma-band oscillatory activity during ambiguous perception**

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Previous EEG studies have suggested a functional role for increased Gamma-band activity during object perception. The neural sources of this oscillatory response during perceptual decision concerning ambiguous stimuli remain elusive. Here we have recorded simultaneous EEG/fMRI signals during a visual perception task using ambiguous stimuli. Data were acquired from 10 healthy subjects that performed a forced choice discrimination task between Mooney categories (prototypical upright and inverted faces, prototypical guitars and scrambled versions) stimuli. EEG MR gradient and pulse artifacts were corrected offline using Independent Component Analysis. Epochs were obtained locked to the stimuli and event-related potential (ERP) measures, time-frequency analysis and fMRI informed source localization were performed. Behavioural data show that subjects discriminate between categories with high performance levels (>75%). We replicated the typical N170 peak and found oscillatory activity was enhanced within the high beta/low gamma range (20-40Hz) locked to the perception moments. The latencies of oscillatory activity peaks were used as general linear model (GLM) predictors for fMRI source localization. We found that different gamma sources are related to perception, spanning from temporal areas to parietal and frontal regions.

◆ 158 **Interactions between perceptual and endogenous processes as reflected in slow EEG oscillations**

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Interactions between stimulus-induced perceptual and endogenous processes play an important role for the high efficiency of the human brain to detect relevant information. A repeatedly reported reflection of cognitive processes in slow EEG components is their enhancement during recognition ("old-new effect"). However, we have shown that this effect is reversed under high visual load. Our study indicates that whether old-new categorisations rely on differences or similarities between the memorized and current percept, is influenced by the stimulus material. Hence, the impact of stimulus-dependent processing on endogenous cognitions modifies slow EEG components (Mathes et al., 2012, Psychophysiology, 46,920-32). Vice versa, the impact of endogenous cognitions on perception can be observed during multistable perception, during which one invariant stimulus pattern is perceived in at least two different, mutually exclusive ways. We have shown that voluntary control of holding and changing the current percept modifies slow oscillatory components during the conscious recognition of the perceptual change (Mathes et al., 2006, Neuroscience Letters, 402,145-49). Recent results further indicate topographical differences of the brain response between internally generated or exogenously applied changes of the percept. In conclusion, memory and perception are interacting and flexible, but in a context-dependent manner.

◆ **Induced Gamma-Band Brain Responses to Direct Eye Contact**

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Recent neuroimaging studies on the perception of facial expression have elucidated that the changes in eye gaze directed to the observer evoke specific neural responses in the posterior inferior temporal and posterior superior-temporal regions. However, it is still unclear how the changes in the eye gaze direction between the directly facing subjects changes the spontaneous brain activities in both subjects. In this study, we used simultaneous recordings of the neuromagnetic (MEG) and EEG on a pair of directly facing subjects, i.e., the sender and the observer of the eye gaze, to measure changes in the spontaneous brain activities while the observer perceives changes in eye gaze direction of the sender. The MEG signals were analyzed in the time-frequency domain to evaluate event-related changes in the spontaneous brain activities induced by the onset of eye movements. Significant increase in the gamma-band power was observed in the eye-contact condition compared to the averting condition in the right superior parietal, bilateral posterior superior-temporal, and the frontal areas of the observer. The increase in gamma-band activities in these regions might reflect the recruitment of the human mirror neuron system during the perception of gaze direction of the directly facing individual.

◆ **Inter-areal causal interactions in the Gamma and Beta frequency bands define a functional**

160 **hierarchy in the primate visual system**

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Cortico-cortical connectivity has been shown to be hierarchically organized such that bottom-up and top-down information are conveyed through the well-defined feedforward and feedback counter-streams, respectively. It remains however unclear what mechanisms the cortex might use to functionally segregate these different paths of information flow. In line with recent studies, showing that Gamma rhythms are predominantly found in the supragranular layers whereas Beta rhythms are strongest in the deep layers (Buffalo et al., 2011), we analyzed causal interactions in the Gamma and Beta frequency bands between seven visual areas of macaque monkeys performing a visuospatial attention task. LFP signals were recorded through electrocorticography and analyzed through spectrally resolved Granger causality. We show here that Gamma-band influences were predominant in the bottom-up direction, whereas Beta-band influences were predominant in the top-down direction. The functional asymmetry we identified was significantly correlated with anatomical data and was used to build a hierarchy model from functional data alone, which was highly similar to anatomical models of the primate visual system. These results open the possibility for the in vivo investigation of functional hierarchies in the healthy and diseased human brain. JV, AMB and CB contributed equally. JV was funded by the LOEWE-NeFF.

◆ **Cortical Pulsed-Inhibition Hinders Identification in Briefly Presented Stimuli at Low**

161 **Contrast**

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Cortical and thalamo-cortical oscillations in different frequency bands have been proposed to provide a neuronal basis for discretization of perception [VanRullen & Koch, 2003, TICS, 7, 207-313]. When the amplitude of occipital alpha oscillations is higher than some threshold cortical excitability, a pulsed inhibition might result in discrete perception [Mathewson et al. 2011, Frontiers in Psychology, 2]. Here, we studied the effect of pulsed inhibition on stimuli presented with supra- and near threshold contrast, in an identification task. The task was to report back the orientation of a Landholt ring presented in high and low contrast. Variable fixation period helped avoid task-induced phase locking of alpha. Alpha oscillations were derived by band-pass filtering the raw EEG data between 8 and 15 Hz and behavioral data was fitted with a Poisson Counter model of identification after classifying the trials based on the average phase distribution prior to stimulus onset of correct and wrong responses. A grand average counter-phase stimulus-locked alpha oscillation between correct and wrong responses was present in the low but not in the high contrast condition. When stimuli contrast is high, the preceding oscillatory activity does not play a role since stimulus evoked cortical excitability is well above threshold.

POSTERS : NEURONAL MECHANISMS OF INFORMATION PROCESSING

◆ **Disinhibition Among the Extra-Classical Receptive Field of Retinal Ganglion Cells**
162 **Contributes to Color Constancy**

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The retinal ganglion cells (RGCs) of monkeys have a difference-of-Gaussian (DOG) shaped classical receptive field (CRF). We have found that the region beyond the CRF center is quite extensive, and this region shows disinhibitory effect, which reduces the strength of surround inhibition exerted on the CRF center. We have previously proposed that this extensive region (named extra-classical receptive field, ERF) is comprised of many inhibitory subunits, which first inhibit each other, and then inhibit the classical RF center. In this study, we further propose that ERF of single-opponent color RGCs is also composed of subunits. For example, for a RGC with R+G- single-opponency, the subunits in its surround (inhibitory Green component) first inhibit each other, and then the inhibited Green subunits inhibit the response of classical RF center to the Red channel. Our simulation results show that for a color-biased scene, the disinhibition in ERF has the potential to remove the unwanted (inhibitory) effect of the extensively spread external light in the extensive ERF, and hence keeps the color component in the RF center unbiased as much as possible. We suggest that the disinhibition property in single-opponent RGCs contributes substantially to the perceptual ability of color constancy.

◆ **Can the imaging process explain ganglion cells anisotropies?**
163

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The statistics of the natural environment have been characterized to gain insight in the processing of natural stimuli under the efficient coding hypothesis. However, much less work has considered the influence of the imaging system itself. Here we use a model of the human imaging process that shapes the local input signal statistics to the visual system across the visual field. Under this model, we have shown that the second order statistics of naturalistic images vary systematically with retinal position [Pamplona et al, 2013, Vision Research, 83,66-75]. In the present study, we investigate the consequences of the imaging process on the properties of retinal ganglion cells according to a generative model encompassing two previous approaches [Dong and Attick, 1995, Network: Computation in Neural Systems, 6, 159-178; Doi, 2006, Advances in neural information processing]. Our results agree with previous empirical data reporting anisotropies in retinal ganglion cells' receptive fields and thereby provide a functional explanation of these properties in terms of optimal coding of sensory stimuli [Croner and Kaplan, 1995, Vision Research, 35,7-34; Passaglia et al, 2002, Vision Research, 42, 683-694]. We conclude by providing a detailed quantitative analysis of model retinal ganglion cells across the visual field.

◆ **Modeling study of orientation sensitivity of lateral geniculate nucleus neurons**
164

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It was experimentally shown that orientation selectivity is characteristic of not only cortical but also dorsal lateral geniculate nucleus (LGN) neurons in cats. In our work it is shown that cat LGN neurons are sensitive to the orientations of both stimuli, a bar and a brightness gradient. Orientation selectivity index (OSI) is computed as OSI =(Nmax-Nmin)/Nmax, where Nmax and Nmin are amplitude of the responses to preferred and non-preferred orientations of the stimuli bar. The mean value of OSI for 37 neurons is equal to 0.49±0.07 (bar) and 0.59±0.06 (brightness gradient) ($p<0.05$). With the help of mathematical modeling the factors that might influence the measurements of orientation selectivity are analyzed. Model responses on two types of stimuli are qualitatively consistent with experimental data. It was shown that the non-zero orientation selectivity index may be caused by either the elongation of receptive field together with nonlinear saturation effects or the shift of the receptive field center relative to the stimulus center.

◆ **Effects of binocular flash suppression in the anesthetized macaque**

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The primary visual cortex (V1) was implicated as an important candidate for the site of perceptual suppression in numerous psychophysical and imaging studies (Lehky, 1988; Blake, 1989; Polonsky et al., 2000; Tong and Engel, 2001). However, neurophysiological results in awake monkeys provided evidence for competition mainly between neurons in areas beyond V1 (Leopold and Logothetis, 1996; Sheinberg and Logothetis, 1997). In particular, only a moderate percentage of neurons in V1 was modulated in parallel with perception and the magnitude of their modulation was substantially smaller than the physical preference of these neurons (Keliris et al., 2010). It is yet unclear whether these small modulations are rooted in local circuits in V1 or influenced by higher cognitive states. To address this question we recorded multi-unit spiking activity and local field potentials in area V1 of anesthetized macaque monkeys during the paradigm of binocular flash suppression. The results showed that the pattern of perceptual modulation of neurons in V1 under the conditions of general anesthesia is almost identical to those recorded from awake monkeys. This suggests a role of local processes in V1 in perceptual suppression. Alternatively, these modulations could be caused by feedback from higher areas independent of conscious state.

◆ **Pattern motion signals from V1 receptive fields**

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Local measurements by small receptive fields (RFs) in V1 are thought to induce ambiguous and noisy one-dimensional motion estimation. This necessitates integration at higher brain stages for computation of global pattern motion. Electrophysiological evidence from monkeys viewing plaid stimuli is consistent with this hypothesis finding a small percentage of cells in V1 responding to pattern motion but the percentage is increasing in higher motion responsive areas MT and MST. We conjectured that a subset of V1 RFs residing on specific stimulus features could directly respond to the pattern motion thus biasing motion integration at higher stages. We used a novel stimulus to mimic V1 RF responses to plaids. It comprised of a mask with multiple transparent apertures (0.4°) over a moving plaid. The aperture locations were chosen in advance to be of two types: AP1 were chosen to "see" only single grating components at any given time while AP2 were chosen to "see" only grating intersections. We manipulated the percentage of these two types in different trials to test how they influence motion perception. We found that the motion perception of subjects changes sigmoidally from 100% transparent when all apertures are AP1 to 100% coherent when all apertures are AP2.

◆ **Decoding pattern motion information in V1**

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Two superimposed drifting gratings can be perceived as two overlapping gratings or as a pattern. Previous studies have found pattern motion processing only from V2 onwards. Using multivariate pattern analysis we investigated whether pattern motion is processed as early as in V1. In experiment 1, we presented superimposed sinusoidal gratings with varying angles, perceived as patterns moving in two different directions. Participants performed a fixation task and a speed discrimination task. Eye tracking was performed to ensure proper fixation. Polar angle retinotopic mapping and a functional hMT+/V5 localiser were used to define regions of interest (ROIs). A classifier was trained to discriminate the two pattern directions. We could decode the two pattern directions significantly above chance in all ROIs. Cross-classification was performed between stimulus pairs with different angles. Again, decoding accuracies were significantly above chance, and did not differ between any of the cross-classifications in any of the ROIs. This suggests the classifier did not use component motion signals, but pattern motion information. This conclusion was verified by experiment 2, where we manipulated the perception of square wave gratings to yield either pattern or component motion perception. Our results indicate that pattern motion information is present already in V1.

◆ 168 **Characterization of monkey V1 local field potentials as recorded by different types of chronically implanted multi-electrode arrays**

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Chronically implanted multielectrode arrays (MEAs) allow studying dynamic interactions within large neuronal populations. They have become an important tool in basic neuroscience and constitute a promising approach for future neuroprosthetic and –therapeutic applications. The majority of current arrays use intracortically implanted electrodes that allow recording both single unit activity and local field potentials. For medical purposes, however, epidurally implanted electrodes are more favorable since they do not penetrate dura or nervous tissue. Here, we investigate different chronic approaches with a focus on two issues: first, comparison of the stimulus specificity of local field potentials recorded either intracortically or epidurally, and second, long-term stability of recordings. Responses from primary visual cortex were recorded by four different MEA types and were obtained for prolonged periods of time, lasting to a maximum of six years. The results show that epidurally recorded LFPs possess a high stimulus specificity closely resembling that of intracortically recorded LFPs and can be detected with high reliability even many years after implantation. Thus, epidural electrode matrices fulfill an important pre-requisite to use intracranial neural signals for medical purposes.

◆ 169 **A new and effective automated procedure for mapping monkey V1 receptive fields built on induced responses**

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Investigating the dynamic interactions in large populations of neurons requires recordings with many electrodes simultaneously. However, massive parallel recordings complicate the mapping of discrete receptive fields (RFs) and therefore critically depend on fast and reliable automated procedures. Such procedures usually utilize briefly flashed stimuli and rely on transient firing rate increases and evoked changes in the local field potential (LFP), even though experimental investigations often consider longer-lasting responses. We therefore tested a mapping protocol relying on the sustained, induced neuronal activity, using moving bars of different orientations. Based on chronic, intra-cortical recordings in primary visual cortex (V1) of macaque monkeys, we compare our bar mapping method with a standard 'flashing dots' procedure. We investigated RF properties from three different signals: spikes, the rectified and low-pass filtered multiunit signal, and the gamma-band LFP. The bar mapping procedure revealed RFs of similar size, position and signal-to-noise ratio as compared to RFs from the same recording site measured with the dot mapping technique. Furthermore, the bar mapping technique requires a smaller number of trials and provides information on direction and orientation selectivity of the individual units.

◆ 170 **The spatial summation characteristics of three categories of V1 neurons differing in non-classical receptive field modulation properties**

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The spatial summation of excitation and inhibition determines the final output of neurons in the primary visual cortex (V1) of the cat. To characterize the spatial extent of the excitatory (CRF) and inhibitory (nCRF) areas, we examined the spatial summation properties of 153 neurons in cat V1 at high (20-80%) and low (5-15%) contrast. Based on the differences in contrast dependency of surround suppression, the V1 neurons were classified into three categories. Our results revealed that size of CRF and nCRF were different between the three categories. It is shown that the type II cells have significantly larger CRFs and nCRFs than those of type I cells, and the CRFs of type III cells were the largest among the three categories, but the difference between type II and type III was not significant. Furthermore, the three categories also differ in the proportion of simple cells to complex cells, there were more complex cells than simple cells, in comparison, more simple cells were found in the type III cells.

◆ **Detection of Orientation Continuity and Discontinuity by Cat V1 Neurons**

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Orientation tuning properties of the non-classical receptive field (nCRF or "surround") relative to that of the classical receptive field (CRF, or "center") were tested for 119 neurons in cat primary visual cortex (V1). Based on the presence or absence of surround suppression measured by suppression index at the optimal orientation of the cells, we subdivided the cat V1 neurons into two categories: surround-suppressive (SS) cells and surround-non-suppressive (SN) cells. For the SS cells, strength of surround suppression was dependent on the relative orientation between CRF and nCRF, iso-orientation grating over center and surround at the optimal orientation evoked strongest suppression and surround grating orthogonal to the optimal center grating evoked weakest or no suppression. In contrast, the SN cells showed slightly increased response to iso-orientation stimulus and weak suppression to orthogonal surround gratings. This iso-/orthogonal orientation selectivity between center and surround was analyzed for 22 SN cells and 97 SS cells, respectively, and the results showed that the SN cells inclined to detect continuity or similarity of orientations between CRF and nCRF, and the SS cells mostly detected the discontinuity or difference in orientation between CRF and nCRF.

◆ **Spatio-temporal architecture of orientational functional clusters in cat's primary visual**

172 **cortex**

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Intrinsic optical imaging technique provides us a micro-level window to study the nature of neural mechanism from neural cluster's activities. But how to acquire useful neural activities from low signal-to-noise (SNR) intrinsic optical images has always been a difficult problem. Traditionally, using global mean on many repeats or by overlapping similar images, the low SNR can be improved to a certain extent. For example, according to "180 degree similar and 90 degree reverse" principal, the famous orientational "pinwheel" graph can be computed. However, in practice, this principal is difficult to be satisfied due to very low SNR. In our work, adopting PCA and spatial ICA, we acquired high-quality orientational functional map from original low SNR optical images. It is worth mentioning that our method can be carried out from few repeats and no need of "similar or reverse" principal. Further, some micro-architectures in cluster in the functional map were discussed. Moreover, the related temporal courses of the functional clusters were also studied to observe the change of neural activities to dynamic visual stimuli. We deem that combing spatial architecture and its temporal course is more meaningful to understand the biological visual neural mechanism.

◆ **A Single Learning Rule can Account for the Development of Simple and Complex Cells**

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Understanding the human visual system and the underlying learning mechanisms is a vital need for computational models of perception. One open question for the development of such models is how the visual system achieves its ability to recognize objects invariant to various transformations. To study potential mechanisms for learning this invariant processing, we created a multi-layer model of the primary visual cortex (V1). The model consists of an input layer simulating the LGN input into V1, the so-called simple-layer related to V1-layer 4, and the complex-layer related to V1-layer 2/3. In our previous work [Teichmann et al, 2012, Neural Computation, 24(5), 1271-96], we found that trace learning is a suitable mechanism for learning the responses of V1 complex cells. Here we show that a single learning rule can account for the development of simple- as well as complex-cell properties. We apply this learning rule to exploit the temporal continuity of the visual input, using a short-term trace for neurons in the simple layer and a longer-term trace in the complex layer. We show that neurons in the simple layer develop receptive fields comparable to monkey data, while neurons in the complex layer exhibit phase invariance.

◆ **Modelling Responses to Uncomfortable Images**

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The visual system is thought to be optimised to encode typical natural images, to keep the metabolic costs of processing low (Barlow, 1961, in: Sensory Communication, W. A. Rosenblith, MIT Press). Field (1994, Neural Computation, 6, 559-601) showed that natural images are efficiently (sparsely) coded by a model visual system consisting of wavelet filters, based on known properties of cells. Images deviating from the statistics of natural images, e.g. stripes, have been shown to cause viewing discomfort, such as headaches, eyestrain, and distortions of vision (Wilkins et al, 1984, Brain, 989-1017). Juricevic et al (2010, Perception, 884-899) suggested that discomfort could occur when images create an excessive neural response. The current study used a simple, physiologically based model of V1 to assess the sparseness of the response to uncomfortable stimuli. The kurtosis of the population response to uncomfortable images was lower than to natural images, and showed the same spatial frequency tuning as discomfort judgements. This suggests that the population response to uncomfortable images is less sparse compared to natural images, supporting the suggestion that discomfort can be caused by excessive metabolic demands.

◆ **Amplitude and frequency characteristics of attentional modulation of gamma-band**

175 **synchronization within and between monkey areas V1 and V4**

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Gamma-band synchronization (GBS) has been proposed to serve as a mechanism of selective attention. We have previously reported enhancement of local, intra-areal GBS in V4, when attention was inside the V4 receptive field (RF). Recently, we also reported inter-areal GBS between V4 and V1. A local V4 population selectively synchronized with only one of its multiple V1 input populations, namely that one representing the attended stimulus. Here, we characterize the interactions between intra- and inter-areal GBS in more detail; in particular frequency, timing and amplitude modulations of intra- and inter-areal GBS with attention. The monkeys had to attend one of two simultaneously presented, non-overlapping shapes, placed within the same V4 RF. Attention could be directed in- or outside the V1 RF, but was always within the V4 RF. For both monkeys, we found a clear increase in V1 gamma-band power with attention inside the V1 RF. The peak frequency of the inter-areal GBS was similar to that of the local V1 GBS, whereas the local V4 peak frequency was higher. Our findings might indicate that the local V1 GBS is fully engaged in the selective inter-areal routing process whereas other processes and interactions contribute to the V4 GBS.

◆ **Improved information processing under attention is explained by phase transitions in**

176 **cortical dynamics**

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Attention improves processing of visual stimuli and is required for perceiving complex shapes and objects. Electrophysiological studies investigating the neural correlates of selective visual attention revealed a strong increase of oscillations in the gamma frequency band (35-90 Hz) in visual cortical neurons. This indicates that gamma oscillations are relevant for optimizing information processing under attention, but their functional role is currently not understood. Here we explore the relationship between increased synchrony and stimulus representation in a network of integrate-and-fire neurons. By increasing the efficacy of recurrent couplings, attention enhances spontaneous synchronization and renders activation patterns for different external stimuli more distinct. This result is in good agreement with recent experimental evidence [Rotermund et al., J. Neurosci. 29 (2009)]. Combining mathematical analysis of the network dynamics with parametric simulations reveals that the effect is particularly strong at the phase transition from a state of irregular activity towards a synchronized state. At this point, power-law distributions of synchronous events (avalanches) occur, which are characteristic for so-called 'critical' states. If cortical networks indeed operate at such a critical point, fine modulations of synaptic strengths lead to dramatic enhancements of stimulus representations, suggesting a functional role for synchronization and criticality in cortical information processing.

◆ **Sparse representation in the construction of curvature selectivity in V4**

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Physiological studies have reported that V4 neurons are selective to curvature and its direction, and their population preference is biased toward acute curvature [e.g., Carlson et al., 2011, Current Biology, 21, 288-293]. Although these characteristics appear crucial for the primitive representation of shape, what principle underlies such complex selectivity has not been clarified. We propose that sparse representation is crucial for the construction of the selectivity, as similar to V1 [Olshausen and Field, 1996, Nature, 381, 288-293]. To test the proposal, we applied component analysis with sparseness constraint to activities of model neurons, and investigated the dependence of basis functions on sparseness. The computed bases represent the receptive field that is generated given the constraint. The structures of the bases were localized and appeared to represent curvature when sparseness is medium to large (>0.6). To investigate whether these bases reproduce the characteristics of V4 neurons, we computed selectivity of each basis in curvature/direction domain, and their population preference, in the way same as the physiological experiments. The selectivity of bases and their population preference agreed with the physiology when sparseness was medium (0.6-0.8). These results indicate that medium-to-large sparseness is crucial for the construction of curvature selectivity in V4.

◆ **Cortical area MT+ plays a role in monocular depth perception**

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Last year at ECVP 2012, we reported that luminance-contrast smoothness is useful as one of depth cues. On top of that, we found that increase of the luminance-contrast smoothness enhances depth perception. To understand what neural mechanism underlies the perceptual phenomenon, we conducted a series of fMRI experiments. Two same-sized bars were vertically presented on the display. To make those bars to have depth information, both bars contained the gradual luminance-contrast change from one side to the other (LtoR or RtoL) [O'Shea et al, 1994, Vision Research, 33, 1595-1604]. The smoothness of luminance-contrast change were varied by manipulating the resolution of the stimuli, and one had higher and the other had lower smoothness. In fMRI scanner, participants were asked to report which bar they perceived more depth (Depth task). In a separate session, they were engaged to report which bar was darker, with the same stimulus set used in the depth task (Luminance task). Both tasks were conducted with monocular viewing. As a result, we found that the depth task condition more strongly activated human middle temporal (MT+) than the luminance task condition. This finding suggests that MT+ plays an important role in monocular depth perception.

◆ **Transient responses in area MT facilitate speed change detection**

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In a recent study, we found that reaction times in a speed change detection task closely correlate with the latency of transient responses in area MT. Here, we investigate how these transient responses are related to the sign and amplitude of a wide range of positive and negative speed changes, and how they depend on the underlying speed tuning. We find that transient rate changes do not simply reflect the neuron's speed tuning, but depend on a multiplicative gain which scales the response according to the speed change amplitude. The strength of this gain correlates with a measure of short-term adaptation, suggesting a computational mechanism at the network level. We show that speed change detection at or even above the behavioral level can be explained by a simple, physiologically plausible threshold model based on the summed input of a limited number of both optimally and non-optimally speed-tuned neurons. Moreover, we show that transient response amplitudes and latencies can explain a recently identified eccentricity-dependent detection bias. We present a unifying explanation regarding the difference between detection thresholds and reaction times in their relation to speed change amplitudes, which may be extended to detection of rapid changes in visual input in general.

◆ **Task-specific and feature dimension-based attentional modulation of neural responses in visual area MT**

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Visual attention modulates neuronal responses in early visual cortex based on spatial location, object affiliation and features. However, it is not clear how task-specific requirements on visual perception influence the recruitment of these attentional mechanisms. For example, if the task requires the detection of a motion change, are motion-sensitive neurons activated differently than for a task in which motion is not important? We investigated this issue by recording from visual area MT neurons. The monkey had to detect either a speed or a color change of a Gabor stimulus at a pre-cued spatial location. When the monkey attended the speed change of the stimulus, MT neurons exhibited higher firing rates and reduced latencies as compared to attending the color change of the otherwise physically identical stimulus. Interestingly, we found that this attentional modulation is independent of motion direction and spatial location. Our results suggest that attention modulates neural activity in a dynamic manner dependent on the task requirements and resulting in a specific attentional modulation of the cortical module processing the selected feature dimension.

◆ **A Neurodynamical Model of Visuo-spatial Selection**

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D Domijan (Department of Psychology, University of Rijeka, Croatia; e-mail: ddomijan@ffri.hr)

Huang and Pashler [2007, Psychological Review, 114(3), 599-631] showed that observers are able to simultaneously select all spatial locations occupied by a single feature value (e.g., red) per dimension (color). They suggested that visual system creates a Boolean map, that is, a spatial representation which partitions visual scene into two distinct and complementary regions (selected and not selected). The aim of the present work is to develop a recurrent neural network with the ability to select multiple visual objects simultaneously based on a shared feature value. The basic computational elements of the network are two types of inhibitory interneurons which mediates lateral and dendritic inhibition. Lateral inhibition implements competition between locations, while dendritic inhibition enables spatial grouping and feature-based selection. Interactions between lateral and dendritic inhibition result in a formation of a spatial map where maximal firing rate is assigned to selected feature value while neural activity at other locations is suppressed. Computer simulations showed that the proposed neural network is able to create a Boolean map and to elaborate it using logical operations of intersection and union. The proposed network provides a neural implementation of the Boolean theory of visual attention.

◆ **Effects of complex background scene on object selectivity of single-unit activities in the macaque inferior temporal cortex**

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M Mukai[1], Y Yamane[1], J Ito[2], S Gruen[2], H Tamura[1] ([1]Graduate School of Frontier Biosciences, Osaka University, Japan; [2]Statistical Neuroscience, INM-6 & IAS-6, Forschungszentrum Juelich, Germany; e-mail: tamura@fbs.osaka-u.ac.jp)

The inferior temporal (IT) cortex is a higher visual area that is crucial for visual object recognition. Studies of IT neurons have been focused on responses to isolated objects presented on a plain background. However, because objects in realistic conditions are placed in complex background scenes and receptive fields of IT neurons are large, object representation of IT neurons may involve interactions between objects and their background. We investigated whether and how the presence of a complex background scene affects the responses of IT neurons to object images. We prepared 448 images (64 objects on 6 natural-scene and a plain backgrounds) as visual stimuli. The spiking activities of IT neurons were recorded from analgesized and immobilized monkeys (Macaca fuscata). We identified 75 visually responsive neurons out of 110 recorded neurons, but 63 of these 75 neurons were responsive only when the objects were on particular backgrounds, indicating that the presence of complex background scene affects the responsiveness of IT neurons to the objects. For those neurons that were visually responsive for multiple background scenes, their object preference was preserved across different background scenes. These response properties of IT neurons are suitable for the invariant recognition of objects across different backgrounds.

◆ **Effects of complex background scene on object selectivity of current source density activities in the macaque inferior temporal cortex**

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J Ito[1], M Mukai[2], Y Yamane[2], H Tamura[2], S Gruen[1] ([1]Statistical Neuroscience, INM-6 & IAS-6, Forschungszentrum Juelich, Germany; [2]Graduate School of Frontier Biosciences, Osaka University, Japan; e-mail: j.ito@fz-juelich.de)

In our daily life, visual objects do not appear in isolation, but are embedded in a complex background. Furthermore, since objects are typically brought into the fovea by eye movements, there is a sudden change of the background just before the objects are foveated. Here we studied whether and how complex background and its sudden change affect the object-selective neuronal activities in the inferior temporal cortex of macaque monkeys by analyzing the current source density (CSD) signals, which reflect the local synaptic processes. We presented visual objects to analgesized and immobilized monkeys either (A) on a gray background, (B) on complex backgrounds during prolonged presentations of these backgrounds, or (C) on complex backgrounds that were switched from a gray background simultaneously with the appearance of the object. We found that the object preference of the object-selective CSD activity was considerably modified when objects were embedded in complex (condition B) instead of gray backgrounds (condition A), but the sudden change of background (condition C) canceled this modification and also enhanced the CSD response magnitude. We discuss the implications of these results to the visual processing in natural conditions such as active visual search of objects embedded in natural scenes.

◆ **Processing of object selectivity across cortical layers in the inferior temporal cortex**

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The inferior temporal (IT) cortex is known for object recognition since IT neurons selectively respond to specific, complex visual objects (Tanaka, 1993, Science, 262:685-688). Here we aim to test the hypothesis that object selectivity is processed within IT across the cortical layers. Therefore we recorded simultaneously the neuronal activities in form of the local field potentials (LFP) from multiple depths of IT cortex using a linear electrode array in analgesized and immobilized monkeys. The monkeys were presented with 128 complex visual objects each separately shown on a gray background for 0.5 sec. From the amplitudes of the LFPs (bandpass filtered 1.5-300 Hz) during the stimulus presentations we computed the selectivity index (SI) defined as across-stimulus response variance divided by within-stimulus variance (Kreiman et al, 2006, Neuron, 49:433-445). At about 100ms after stimulus onset we observed a negative deflection in the LFP amplitude in the granular layer which is typically not associated with high SI value. Later at 230ms after stimulus onset there was a second, strong negative deflection spanning all layers which is associated with strong selectivity also observed in all layers. This suggests a transformation of non-specific input activity to object-selective output of IT cortex.

◆ **Visual Sensitivity of Frontal Eye Field Neurons During the Preparation of Saccadic Eye Movements**

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R Krock, T Moore (Neurobiology Department, Stanford University, CA, United States; e-mail: becca.krock@gmail.com)

Saccadic suppression is a well-characterized psychophysical phenomenon in which visual sensitivity decreases profoundly just before and during saccades. It is thought to play a role in minimizing the perception of self-generated motion signals. The visual responses of neurons before and during saccades have been investigated at numerous stages of the primate visual system, but a clear neural correlate of saccadic suppression remains elusive. We measured the visual sensitivity of neurons in the frontal eye field (FEF), a visuomotor area that is causally involved in generating saccadic eye movements, during the preparation of saccades. We functionally characterized neurons as having visual, visuomovement, or movement activity using a memory-guided saccade task. For cells with visual or visuomovement activity, we recorded visual responses to brief (8ms) visual probes consisting of full-field, 0.1 cycles/degree sinusoidal gratings ranging from 2% to 32% Michaelson contrast. We compared the contrast sensitivity of neurons to probes presented long (>100ms) or immediately (<100ms) before saccades. Our results suggest how the representation of visual stimuli in the FEF might account for the changes in visual sensitivity that precede saccades.

◆ **Encoding of stimuli in the primate dorsolateral prefrontal cortex is improved by noise correlations**

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The primate dorsolateral prefrontal cortex (dlPFC) plays an important role in visual attention. How neurons interact with one another during the allocation of attention remains unclear. We recorded neuronal activity in the left dlPFC of a macaque using a 96-electrode microarray while the animal identified the target stimulus based on a color cue, allocated attention to it, and indicated a change in one of its features while ignoring similar changes in a distractor. We investigated interactions between 607 neurons during the cue presentation and sustaining of attention. One third of the neurons (168) fired more strongly when the attended stimulus was at a particular location (ipsi- vs. contralateral). Noise correlations (Cnoise) amongst neuronal pairs were significantly different from chance during the analyzed periods. We used a support vector machine to assess whether Cnoise had an impact on the neuronal population ability to encode the attended location. Compared to simultaneously recorded trials, shuffling trials across neurons significantly decreased decoding performance (70% to 49% and 89% to 83% during cue presentation and sustained attention, respectively). These results demonstrate that removing interactions between dlPFC neurons reduces the amount of information carried by neuronal populations within this area about the locus of attention.

◆ **Hyperacuity, pattern recognition and binding problem: what fractals may tell us**

187 T Kromer (Center for Psychiatry Südwürttemberg, Germany; e-mail: thomas.kromer@t-online.de)

Mandelbrot and Julia sets are generated by iterated projections (function: f(z)=z*z + c) of the complex plane to itself[Mandelbrot, 1983, The fractal geometry of nature, New York, Macmillan]. We reach z*z by the logarithmic spiral through z to the doubling of the angle to the x-axis. Combining spiralic and straightlined movement of addition of vector c, we get spiralic trajectories. Assuming neurons, representing complex numbers, send their axons along those strictly topographic trajectories to subsequent neurons, we get neural nets with a very rich connectivity. Regions of the whole net will be connected more or less strongly with any part of the net and vice versa by recurrent connections. Each neuron will represent a pattern of the whole net, eventually important for binding problem and pattern recognition. Neighboured neurons will represent similar but not identical patterns. Divergent axones will separate activities, overlapping at the input layer, after few iterative projections contributing to hyperacuity. Within the Mandelbrot set, we find a central structure, resembling to a thalamus, with ipsi- and contralateral connections and similar structures in threedimensional equivalents of Mandelbrot or Julia sets. Studying fractal neural nets may improve our understanding of structure and function of the human brain.

◆ **A model of selective visual attention predicts biased competition and information routing**

188 D Harnack, K Pawelzik, U A Ernst (Institute for Theoretical Physics, University of Bremen, Germany; e-mail: daniel@neuro.uni-bremen.de)

Selective visual attention allows to focus on relevant information, and to ignore distracting features of a visual scene. These principles of information processing are reflected in response properties of neurons in visual area V4: If a neuron is presented with two stimuli in its receptive field, and one is attended, the neuron responds as if the non-attended stimulus was absent (biased competition). In addition, when the luminances of the two stimuli are temporally and independently modulated, local field potentials are correlated with the modulation of the attended stimulus, but not with the non-attended stimulus (information routing) [Rotermund et al., SfN Annual Meeting 2011, #221.05]. In order to explain these results in one coherent framework, we present a two-layer spiking cortical network model with lateral connectivity and converging feed-forward connections. When driven near the oscillatory regime, it reproduces both experimental observations. Hereby, lateral inhibition and shift of the relative phases between sending and receiving layers (communication through coherence, CTC) are identified as the main mechanisms underlying biased competition and selective routing. Our model predicts a sharpening of the distribution of relative phases together with a positive phase shift of 90 degrees if the stimulus processed by the sending layer is attended.

◆ **Relating cytoarchitectonic differentiation and interareal distance to corticocortical**
189 **connection patterns in the cat brain**

S Beul, C C Hilgetag (Department of Computational Neuroscience, University Medical Center Hamburg-Eppendorf, Germany; e-mail: s.beul@uke.de)

Information processing in the brain is strongly constrained by structural connectivity. However, the principles governing the organization of corticocortical connectivity remain elusive. Here, we tested three models of relationships between the organization of cortical structure and features of connections linking 48 areas the cat cerebral cortex. Factors taken into account were areas' relative cytoarchitectonic differentiation (structural model), relative spatial position (distance model), and relative hierarchical position (hierarchical model). Structural differentiation and distance (themselves uncorrelated) correlated strongly with the existence or absence of interareal connections, whereas no correlation was found with relative hierarchical position. Moreover, a strong correlation was observed between laminar projection patterns and structural differentiation. Additionally, architectonic differentiation correlated with the absolute number of corticocortical connections formed by areas, and varied characteristically between different cortical subnetworks, including a module of hub areas. Thus, structural connectivity in the cat cerebral cortex can, to a large part, be explained by the two independent factors of relative structural differentiation and distance of brain regions. Hierarchical area rankings, by contrast, did not add explanatory value. As both the structural and distance model were originally formulated in the macaque monkey, their applicability in another mammalian species suggests a general principle of cortical organization.

◆ **Merging color and shape in a hierarchical pattern recognition model**
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S Eberhardt[1], C Zetzsche[1], M Fahle[2], K Schill[1] ([1]Cognitive Neuroinformatics, University of Bremen, Germany; [2]ZKW, Bremen University, Germany; e-mail: sven2@uni-bremen.de)

When we're viewing and recognizing objects in natural scenes, shape and color information seem inseparably linked. However, neurobiological evidence suggests that color and shape processing in humans happen in a diverse number of distinct areas within the visual cortex, which provide specialized functionality for each submodality. The exact amount of parallel processing and the point of merging these information channels into a multimodal representation is still disputed. Here, we approach the problem from a computational point of view and adjust a hierarchical feed-forward pattern recognition model [Serre et al, 2007, PNAS, 104(15), 6424–6429] for color processing. We ask at which point modalities should be merged to maximize information in natural image statistics and test classification performance on natural tasks. We find that merging of color and shape should happen late in the processing hierarchy and conclude that parallel processing of submodalities rather than early merging into compound features is advantageous for efficient object recognition.

◆ **Multi-lesion analysis of the cortico-collicular attention network of the cat brain**
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M Zavaglia, C C Hilgetag (Department of Computational Neuroscience, University Medical Center Eppendorf Hamburg, Germany; e-mail: m.zavaglia@uke.de)

Spatial attention is a prime example for distributed network functions of the brain. Lesion studies in animal models have been used to investigate attentional mechanisms and perspectives for rehabilitation. We analyzed systematic data from cooling deactivation and permanent lesion experiments in the cat where unilateral deactivation of posterior middle suprasylvian cortex (pMS) or superior colliculus (SC) caused a severe neglect in the contralateral hemifield. Surprisingly, additional deactivation of structures in the opposite hemisphere reversed the deficit. Using these data, we employed Multi-perturbation Shapley-value Analysis (MSA) to compute causal contributions of bilateral pMS and SC to visual attention. MSA is a game-theoretical method for inferring functional contributions and interactions from behavioral performance. Brain regions are considered players and each coalition of non-lesioned regions has a performance score, here, for orienting to the left visual field. Regions pMSr and SCr made the strongest positive contributions, while pMSl and SCl had negative contributions, implying that their perturbation may reverse the effects of contralateral lesions or improve normal function. Strong negative interactions existed between regions within each hemisphere, while all interhemispheric interactions were positive. It is a challenge to reconcile these causal interactions with the known physiological network for attention in the cat brain.

◆ 192 **Spatial remapping without gain fields: a neural model based on cortico-thalamic connectivity**

B Babadi[1], N Jia[2], P Safari[3], A Yazdanbakhsh[2] ([1]Center for Brain Science, Harvard University, MA, United States; [2]Center for Computational Neuroscience, Boston University, MA, United States; [3]Mathematics Department, Harvard University, MA, United States; e-mail: bbabadi@fas.harvard.edu)

Experimental evidence has identified neurons in the frontal eye field (FEF) whose receptive fields undergo dynamic changes prior to saccade, such that their spatial profile is altered to compensate for saccadic eye movement. It has been long suggested that the receptive field shifts in areas such as FEF can be accomplished by modulation of neuronal gains. However, there is little experimental support for changes in the gain of neuronal responses in such conditions. Besides, implementing such algorithms in real neural substrate is not straightforward. In this work we propose an alternative biologically plausible mechanism for spatial remapping of receptive fields using simple linear-nonlinear neurons with fixed nonlinearity and synaptic connectivity. Based on universal approximation theorem, we show that a modulation in neural gain can be implemented by a neural model with fixed synaptic weights based on the connectivity patterns among the most involved areas in eye movement and receptive field remapping, namely superior colliculus, medial dorsal nucleus of thalamus, and FEF. Numerical simulations confirm the performance of such a model for a wide range of conditions, corresponding to neurophysiological results. The extensions of our results to sensory-motor mapping in other brain areas and implementation of attentional gain fields are discussed.

WEDNESDAY

RANK PRIZE LECTURE

- **Attentional modulation of the processing and perception of visual motion**
  S Treue (German Primate Center, Goettingen; Faculty of Biology and Psychology, Goettingen University; Bernstein Center for Computational Neuroscience, Goettingen, Germany)

Our senses provide much more information to the central nervous system than can be adequately processed. We use attention as a powerful mechanism for shaping cortical information processing to reflect the current relative behavioral relevance of the various pieces of incoming information. One prominent neurophysiological effect of allocating attention is the modulation of neuronal responses in sensory cortex. Studying this modulation in area MT, a particularly well understood sensory area of primate visual cortex, has revealed a wealth of information about the neural correlates of visual attention. I will present experimental findings focusing on the influence of spatial and feature-based attention in areas MT and MST. The attentional modulation appears to have a multiplicative influence on neural responses, but it is still able to create non-multiplicative changes in receptive field profiles and population responses. These physiological effects are well matched to perceptual consequences of allocating attention, namely an enhanced perception of attended objects and aspects at the expense of an accurate representation of visual information and of the perceptual strength of unattended portions of the visual input.

SYMPOSIUM : VISUAL PERCEPTION IN SCHIZOPHRENIA: VISION RESEARCH, COMPUTATIONAL NEUROSCIENCE, AND PSYCHIATRY

- **Introduction: Visual Perception, Psychosis, and Computational Psychiatry**
  P Fletcher (Brain Mapping Unit, University of Cambridge, United Kingdom; e-mail: pcf22@cam.ac.uk)

Introducing this symposium from the perspective of a psychiatrist, I will emphasise the potential value of neuroscientifically-based models of perception in providing the fundamental insights from which to develop our understanding of psychotic illnesses. Such illnesses are characterised by both abnormal perceptions (hallucinations) and beliefs (delusions). Hitherto, there has been a tendency to treat these as separate phenomena and theorists have argued over whether the fundamental problem lies in anomalous perceptions (with normal inference), or faulty inference acting on normal perceptions. Neither explanation has proven satisfactory, and an alternative has been to suggest a need to invoke both disturbed perception and abnormal reasoning in order to explain psychotic symptoms. I would like to highlight the possibility that models of perception discussed in this symposium offer a satisfactory rapprochement in that they dispense with a simple distinction between perception and inference. Rather, they model human perception, learning and belief in terms of hierarchically arranged circuits entailing both feedforward and re-entrant connections at different levels of inference. Such models may offer profound insights into psychopathology, providing a powerful explanatory framework in which a single deficit, operating at multiple levels, may account for the wide range of experiences that characterise the psychotic state.

- **Orientation and Motion Tuning Curves in Schizophrenia**
  B Christensen (Dpt. Psychiatry & Behavioural Neurosciences, McMaster University, Canada; e-mail: bruce.christensen@mcmaster.ca)

Research shows that both abnormal GABA function characterizes Schizophrenia (SCZ). GABA also mediates specific visual-perceptual processes, raising the possibility that SCZ-related visual processing deficits are secondary to GABAergic dysfunction. Moreover, SCZ visual impairment is disproportionate for those tasks supported by the dorsal visual processing stream. Given that orientation and motion direction processing segregate across ventral and dorsal streams, examining stimulus selectivity in these domains can help to ascertain whether (a) GABA-mediated visual deficits are associated with SCZ and (b) such deficits disproportionately affect dorsal stream processing. In this study, SCZ patients (n=25) and healthy controls (n=26) completed 2 tasks that measured thresholds for (a) discriminating left-right coherent motion of a random dot kinematogram embedded in a dynamic noise mask or (b) detecting a horizontal Gabor pattern embedded in a static mask. Masking noise was made up of visual elements that varied in terms of its overlap to either the target orientation or the motion trajectory. Across both

tasks, patients' linear trend was significantly attenuated indicating broader sensitivity thresholds (i.e., tuning curves). These results are consistent with deficient GABAergic inhibition within SCZ visual cortex. However, no differences emerged as a function task type, suggesting that both visual streams are affected.

- **Deficits in the processing of visual context associated with schizophrenia**
  S C Dakin[1], M S Tibber[1], E Anderson[2], V Robol[3] ([1]Institute of Ophthalmology, University College London, United Kingdom; [2]Institute of Ophthalmology & Institute of Cognitive Neuroscience, University College London, United Kingdom; [3]Department of General Psychology, University of Padua, Italy; e-mail: s.dakin@ucl.ac.uk)

There is now emerging consensus that poorer processing of context is a significant contributor to visual deficits associated with schizophrenia. I will review evidence relating to the nature and neural locus of the context-processing deficit and how it can produce performance deficits that can be misattributed to a failure to integrate visual information. Specifically I will report: (1) Reduced surround suppression in SZ extends across some visual dimensions (e.g. contrast, size) but not others (e.g. luminance) suggesting a cortical locus for this deficit. (2) Patients show a reduced susceptibility to the influence of a disruptive-context both (a) when detecting contours (so that people with SZ produce relatively better performance) and (b) when judging orientation of contour-elements (i.e. patients show proportionally less crowding) (3) Poor contour-context processing and generally noisier representation of local orientation explain deficits in contour detection associated with SZ (rather than an integration deficit per se). (4) fMRI reveals smaller population receptive fields (pRF) in early visual cortical areas of people with SZ which could explain these perceptual differences.

- **Loopy inference in schizophrenia**
  S Deneve[1], R Jardri[2] ([1]Group for Neural Theory, Ecole Normale Supérieure, France; [2]Laboratoire de Neurosciences Fonctionnelles, Université de Lille, France; e-mail: sophie.deneve@gmail.com)

Recent molecular and computational studies support the role of inhibition in stabilizing the information flow in complex recurrent networks. Moreover, subtle impairments of excitatory-to-inhibitory (E/I) balance or regulation appear to be involved in many neurological and psychiatric conditions. The current study aims to specifically and quantitatively relate impaired inhibition with psychotic symptoms in schizophrenia. Considering that the brain constructs hierarchical causal models of the external world, we show how a selective dysfunction of inhibitory loops can result in not only hallucinations but also the formation and subsequent consolidation of delusional beliefs. An impairment in inhibition results in a pathological form of inference called "Loopy Belief Propagation", in which bottom-up and top-down messages are reverberated and accounted for multiple times. Loopy belief propagation accounts for the emergence of erroneous percepts, the patient's overconfidence when facing probabilistic choices, the learning of "unshakable" causal relationships between unrelated events and the paradoxical immunity to perceptual illusions, which are all known to be associated with schizophrenia.

- **Neuro-robotics model of visual hallucinations**
  J Y Jun, D-S Kim (KAIST, Republic of Korea; e-mail: dskim@ee.kaist.ac.kr)

Visual hallucinations are characterized by the presence of perceptual experience in the absence of external visual stimuli. Hallucinatory perception has been recently proposed to be compatible with theoretical models within a hierarchical Bayesian framework [Fletcher et al, 2009, Nature Reviews Neuroscience, 10, 48-58; Friston, 2005, Behavioral and Brain Science, 28, 764-766]. In the present study, we hypothesized that imbalance between bottom-up and top-down processing in a hierarchical Bayesian framework may constitute one of the intrinsic bases for visual hallucinations. To this end, we utilized a simple and biologically-plausible model, Hierarchical Temporal Memory (HTM), as the basis for our subsequent computational experiments [Hawkins, 2004, On Intelligence, New York, Henry Holt]. We included a predictive coding scheme to the HTM to investigate visual hallucinatory perception. In order to investigate the emergence of visual hallucinations using this framework, face images were used to train a modified HTM system. In the visual hallucinatory mode, hallucinatory perception can arise from excessive top-down priors. We concluded from the results of our preliminary studies that hierarchical Bayesian networks have the potential to serve as an architectural and algorithmic framework for more mechanistic elucidation of hallucinatory visual perception in normal and dysfunctional brains.

- **Altered contextual modulation of primary visual cortex responses in schizophrenia**
  P Sterzer[1], K Seymour[2] ([1]Visual Perception Laboratory, Charité - Universitätsmedizin Berlin, Germany; [2]Macquarie University, Australia; e-mail: philipp.sterzer@charite.de)

While schizophrenia is commonly linked to high-level cognitive dysfunction, recent models of schizophrenia suggest that these cognitive symptoms reflect a more pervasive deficit, starting with alterations at the earliest stages of sensory processing. Based on previous behavioural work, we tested whether contextual modulation of neural responses in primary visual cortex (V1) is reduced in patients with paranoid schizophrenia. Eighteen patients and 18 control participants underwent fMRI while viewing a central grating stimulus in the presence of a contextual surround grating oriented either orthogonal or parallel to the central grating's orientation. Phase-encoded retinotopic mapping was performed to define V1 regions of interest in each participant individually. In controls, suppression of the fMRI signal in V1 was stronger for parallel compared to orthogonal surround gratings, consistent with previous findings of orientation-specific contextual suppression. In contrast, in schizophrenic patients the surround grating's orientation exerted no detectable influence on fMRI signal suppression in V1. The between-group difference in orientation-specific contextual suppression was reflected in a significant group-by-orientation interaction. By providing direct neurophysiological evidence for a perturbation of early sensory neural mechanisms, our results support current psychobiological models that link alterations of sensory processing to positive symptoms of schizophrenia, such as hallucinations and delusions.

- **Feedback Processes in the Visual System of Psychosis-Prone Individuals**
  C Teufel[1], N Subramaniam[1], V Dobler[2], I Goodyer[2], P Fletcher[1] ([1]Brain Mapping Unit, University of Cambridge, United Kingdom; [2]Department of Psychiatry, University of Cambridge, United Kingdom; e-mail: crt35@cam.ac.uk)

Perception has conventionally been viewed as a feed-forward process with a unidirectional flow of information. This notion has recently been revised to incorporate feedback influences from higher levels of processing onto lower levels. Such a framework has not only been useful in understanding visual perception in healthy observers but it has been hypothesized that it can provide a unified explanation of both hallucinations and delusions in psychotic patients. Here, we report the results of a study in which we used a psychophysical task in combination with fMRI to study certain processes within the visual system that share crucial similarities with hallucinations. In particular, we examined memory-based changes in perception as a model for visual hallucinations. Our findings indicate that vision in psychosis-prone individuals is characterised by a stronger influence of prior object knowledge on perception. We will discuss potential candidate systems underlying this bias, and the implications for models of schizophrenic and healthy vision.

SYMPOSIUM : VISUAL NOISE: NEW INSIGHTS

- **Adding external noise can trigger a change in processing strategy**
  R Allard (Visual Psychophysics and Perception Lab, Université de Montréal, QC, Canada; e-mail: remy.allard@umontreal.ca)

External noise has been widely used to characterize visual processing. When adding external noise it is usually implicitly assumed that the processing strategy is unaffected, i.e. the stimulus is processed by the same mechanisms having the same properties. However, recent findings showed that this noise-invariant processing assumption can be violated. Thus, one cannot assume a priori that the processing strategy is unaffected by the addition of external noise, which limits the usefulness of external noise paradigms and questions previous findings. I will review various conditions in which adding external noise elicited a change in processing strategy, violating the noise-invariant assumption that underlies external noise paradigms.

- **Controversies in dealing with visual noise**
  S Klein, J Ding, D Levi (School of Optometry, UC Berkeley, CA, United States; e-mail: sklein@berkeley.edu)

We will consider three outstanding problems related to visual noise: 1) The great difficulty of distinguishing multiplicative noise from contrast gain control (Klein vs Katkov-Sagi 'singularity'). 2) Assessing the errors that are made when replacing stochastic noise with an analytic model when nonlinearities are present (Klein vs Lu-Dosher). 3) The role of uncertainty in accounting for the differences between experimental results across labs (Klein-Levi vs Dosher-Lu). This presentation will

summarize our previous work on dealing with these controversies. In addition we will discuss three recommendations for resolving these issues: a) Rating responses should always be used so that the ROC slope can be used to assess multiplicative noise. b) Different stimulus conditions should be intermixed and blocked to determine the uncertainty effects. c) Monocular vs binocular experiments can reveal the role of noise. Finally, we will offer new data on three binocular summation tasks that are useful for dealing with these questions: contrast matching, contrast discrimination, location matching. By dealing with all three tasks together most simple models can be eliminated. The discrimination task is the one task that specifically measures noise, the other tasks are needed to constrain the models.

- **Sampling Efficiency and Internal Noise for Summary Statistics**
  J Solomon[1], P Bex[2], S C Dakin[3] ([1]Division of Optometry and Visual Science, City University London, United Kingdom; [2]Department of Ophthalmology, Harvard Medical School, MA, United States; [3]Institute of Ophthalmology, University College London, United Kingdom; e-mail: j.a.solomon@city.ac.uk)

Psychophysically-derived estimates of the efficiency with which observers can estimate various image statistics are of intense interest to researchers working to describe attention. High estimates of efficiency for brief displays suggest pre-attentive, parallel processing. Sampling efficiency is typically inferred from the right-hand side of threshold-vs-(external)noise (TVN) curves. Allard and Cavanagh (2012) instead concentrated on the left-hand side of the TVN curve, where external noise is low. In an orientation averaging task, they argued that observers average only discriminably different elements, giving an effective sample size no greater than 1. We consider an alternative possibility: 'Late' (internal) noise dominates the left-hand side of the TVN curve. Late noise can be defined as random fluctuations in the effective representation of *all* items in a sample, whereas early noise is defined as random fluctuations in the effective orientation of *each* item. We replicated their experiment and find better fits to our data and theirs with a model containing late noise than with their proposed model in which sampling efficiency increases with external noise.

- **Consistency of classification images across noise dimension**
  P Neri (University of Aberdeen, United Kingdom; e-mail: neri.peter@gmail.com)

When measuring the tuning characteristics of visual mechanisms using stimulus noise, it is often assumed that a given mechanism will retain stable behaviour regardless of the dimension probed by the applied noise process. For example, the tuning properties of an edge detector should be similar whether we probe its spatial preference using pixel noise, or whether we probe its orientation preference using orientation noise. I will discuss data where this and related predictions are put to direct experimental test by deriving perceptual filters (classification images) using different noise probes. The data demonstrate that some properties of the detection mechanism are stable under different noise manipulations, while others are not. I will then discuss computational models that may offer an explanation for the observed similarities/differences.

- **Reconciling multiplicative physiological noise and additive psychophysical noise**
  K May, J Solomon (Division of Optometry and Visual Science, City University London, United Kingdom; e-mail: keith@keithmay.org)

In many psychophysical models of contrast discrimination, the contrast signal undergoes nonlinear transduction, and corruption with additive (i.e., stimulus-invariant) Gaussian noise. But physiological noise is often found to be multiplicative (variance proportional to response). A simple Bayesian decoding model of spiking neurons accommodates both findings, showing Poisson-based multiplicative noise at the physiological level, but additive Gaussian noise at the psychophysical level. If the model neurons' contrast-response functions are evenly spaced along the log-contrast axis, the decoded log-contrast has a stimulus-invariant, approximately Gaussian, distribution. At the psychophysical level, this model is equivalent to a log transducer with stimulus-invariant Gaussian noise. A slight manipulation of the neurons' pattern of spacing along the contrast axis makes the model behave much like a Legge-Foley transducer with stimulus-invariant noise. But is the noise on the model's internal signal really stimulus-invariant? It depends on the (arbitrary) choice of units in which we express the model's decoded contrast. We suggest that the transducer in some psychophysical models is just a transform of the stimulus contrast that allows us to express the internal signal in units such that the noise is stimulus-invariant. In this case, the argument that the noise is stimulus-invariant at the psychophysical level is circular.

◆ **Convergent evidence demonstrates the suppressive effects of noise masks**
D Baker (Department of Psychology, University of York, United Kingdom; e-mail: daniel.baker@york.ac.uk)

The noise masking paradigm is widely used to assess visual deficits by measuring detection of targets embedded in broadband white noise. Recent work (Baker & Meese, 2012, Journal of Vision, 12(10):20, 1-12) demonstrates that unwanted suppression from such masks can contaminate estimates of internal variability. The magnitude of suppression can be assessed using a contrast matching paradigm, which measures the perceived contrast of a grating embedded in noise. For both dynamic and counterphase flickering noise at a range of temporal frequencies (1-19Hz), perceived contrast was reduced most severely (a factor of >4) at higher temporal frequencies. This is consistent with threshold elevation results for orthogonal grating masks (Meese & Holmes, 2007, Proc R Soc B, 274: 127-136). A second line of evidence comes from steady state visual evoked potential (SSVEP) measurements of the contrast response function to sine-wave gratings (1c/deg, 5Hz flicker) at the occipital pole (Oz). There was a marked reduction in the grating response when a high contrast noise mask was added at a temporal frequency (7Hz) that is distinct in the Fourier spectrum of the EEG. The implications of gain control suppression, as well as suggestions for how best to estimate internal noise, will be discussed.

SYMPOSIUM : NON-RETINOTOPIC BASES OF VISUAL PERCEPTION

◆ **Constructing stable spatial maps of the world**
D Burr (University of Florence, Italy; e-mail: dave@in.cnr.it)

Constructing a spatial map of the world from visual signals poses major challenges to the brain, given that the images on our retinae change each time we move our eyes, head or body. We suggest that the visual system solves the problem of eye- and head-movements with two systems: a fast-acting mechanism that anticipates and counteracts the action of the saccade, establishing a transient spatiotopy that bridges the transition from one fixation to the next; and a long-lasting system of spatiotopic maps, which develop slowly over time, and represent the world in world-centred coordinates. We support these claims with a series of experiments using classical psychophysics, functional imaging, after-images and saccade-adaptation. We also examine the impact of lack of vision on the development of these maps.

◆ **An attentional pointer account of motion correspondence**
E Hein[1], C M Moore[2], P Cavanagh[3] ([1]Evolutionary cognition, University of Tübingen, Germany; [2]Department of Psychology, The University of Iowa, IA, United States; [3]LPP, Université Paris Descartes, France; e-mail: elisabeth.hein@uni-tuebingen.de)

How does the visual system construct stable object representations when the input is ambiguous and the retinal image changes as objects and viewer move? To investigate this, we used the Ternus display, in which three elements are presented in alternation in two consecutive frames, shifted by one position from one frame to the next. This display can be perceived as one element jumping across the other two and sometimes as all three elements moving together as a group, depending on how correspondence between the elements across the two displays is resolved. Low-level retinotopic mechanisms have been proposed to explain perception in the Ternus display. Output of short-range motion detectors or visual persistence determine between which elements motion appears, and as a consequence how correspondence is resolved. Recent studies, however, have shown that higher-level factors also influence correspondence in the Ternus display. These include the degree of similarity between elements, perceived size and lightness, visual short-term memory, attention, and even lexical information. Moreover, the reference frame of these effects seems to be non-retinotopic. We propose that the establishment of correspondence relies on object-based attentional pointers that determine correspondence based on perceived similarity/togetherness of the elements and then assigns motion accordingly.

◆ **Non-retinotopic motion processing underlies postdictive appearance modulation**
T Kawabe (Human Information Science Laboratories, NTT Communication Science Laboratories, Japan; e-mail: kawabe.takahiro@lab.ntt.co.jp)

The appearance of a visual flash is judged in a temporally sluggish manner. For example, the appearance of a visual flash is judged with a bias toward the appearance of a trailing flash. This modulation of visual appearance is called postdictive appearance modulation. Though several studies have demonstrated phenomenological aspects of postdictive appearance modulation, no consensus exists regarding how postdictive appearance modulation occurs. We discuss the possibility that the visual system relies on retinotopic and non-retinotopic motion signals to bind consecutive flashes as an object and, as a result,

integrates visual features along the motion trajectory of the object. This integration results in postdictive appearance modulation. Based on this idea, we also argue that we need no special schema to explain postdiction; postdictive appearance modulation simply suggests that the visual system has access only to a temporally integrated status of visual features within a spatiotemporally continuous object.

- **Reference-Frame Metric Field (RFMF) Theory of Non-retinotopic Visual Perception**
  H Ogmen[1], M Herzog[2], B Noory[1] ([1]Dept. of Electrical & Computer Engineering, University of Houston, TX, United States; [2]Laboratory of Psychophysics, École Polytechnique Fédérale de Lausanne, Switzerland; e-mail: ogmen@uh.edu)

Retinotopic representations are insufficient in explaining perception under normal viewing conditions. While recent studies showed that processes such as shape, color, motion, search, attention, and perceptual learning take place in non-retinotopic representations, the bases of these non-retinotopic representations remain largely unknown. Here, we propose a Reference-Frame Metric Field (RFMF) theory which articulates how the coordinate systems (reference frames) and the metric of non-retinotopic representations are dynamically established through field interactions. According to the RFMF theory, motion groupings in the retinotopic space generate local motion vectors with an associated reference-frame field spreading in space. Field interactions determine the global organization of how different reference frames are associated with different regions in the perceptual space. Each region in the resulting field is mapped onto a non-retinotopic representation with a spacetime metric established according to a non-Galilean transform. We will present recent results based on Ternus-Pikler, induced motion, and anorthoscopic perception paradigms to illustrate these concepts and to test the predictions of the theory.

- **Perceptual learning through remapping: How presaccadic updating affects visual processing**
  M Rolfs[1], N Murray-Smith[2], M Carrasco[2] ([1]Bernstein Center & Department of Psychology, Humboldt University Berlin, Germany; [2]Department of Psychology & CNS, New York University, NY, United States; e-mail: martin.rolfs@bccn-berlin.de)

Perceptual learning is a selective improvement in visual performance across a number of training sessions, which occurs when the same retinal location is stimulated by a particular visual stimulus. We trained observers in a fine orientation discrimination task, each time presenting a Gabor just before a saccadic eye movement. Performance first improved over five days of training and then transferred to an untrained location during a transfer phase, in which no saccade was executed. This transfer was spatially selective and only affected the retinal location that the stimulus in the training phase would have occupied following the eye movement. We argue that this result reveals the visual consequences of predictive remapping, the anticipatory activation of neurons in many retinotopic brain areas when an imminent saccade will bring an attended visual stimulus into their receptive field [Duhamel et al., 1992, Science, 255, 9092]. Currently we are attempting to identify the visual content of remapping, using a variant of the task that compares the sensitivity of transfer to the trained stimulus orientation.

TALKS : CATEGORISATION AND RECOGNITION

- **Human facial recognition in fish**
  C Newport[1], G M Wallis[2], U E Siebeck[1] ([1]School of Biomedical Sciences, The University of Queensland, Australia; [2]School of Human Movement Studies, The University of Queensland, Australia; e-mail: c.newport@uq.edu.au)

There are currently two conflicting theories of how humans recognise faces: (i) recognition processes are innate, relying on specialised cortical circuitry, and (ii) recognition uses the same neural circuitry as other object classes and is simply a learned expertise. One method to determine the underlying mechanisms is to ask whether animals without specialised neural circuitry, or indeed a cortex, can complete this task. We tested fish to determine whether they could learn to discriminate human faces. Using a two-alternative forced-choice test, four archerfish (Toxotes chatareus) were trained to select a rewarded face image. All fish could select the correct face from 45 distractors with an accuracy of over 75% ($p<0.05$). Humans tested using the same stimuli reached a higher level of performance. However, archerfish performing a much simpler task involving shapes (e.g. cross and square) revealed similar levels of performance, suggesting that fish find human faces just as easy to discriminate as shapes. This study provides the first behavioural evidence that an animal lacking a cortex, and relatively little exposure to human faces, can nonetheless discriminate them to a high degree of accuracy. Our results suggest that a substantial part of the face discrimination task can be learnt.

- **Emerging Faces: The impact of lighting direction on horizontal image structure and facial recognition**
  S Pearce[1], D H Arnold[2] ([1]School of Psychology, University of Queensland, Australia; [2]Perception Lab, University of Queensland, Australia; e-mail: samuel.pearce@uqconnect.edu.au)

It has been shown that horizontal facial image structure (i.e. contrast/power along the vertical axis) is more informative than its vertical counterpart (Dakin & Watt, 2009 Watt, Dakin & Goffaux, 2010). A reliance on horizontal structure might underlie a number of manipulations that impact facial coding, such as the disruptive effect when faces are lit from below, as opposed to above. We assessed this by developing a novel paradigm, wherein facial images were initially filtered so as to only contain horizontal or vertical information. As a trial wore on more information was revealed by broadening the orientation bandwidth of filtering. We found that recognition performance (indexed by response times and accuracy) was generally superior for initially horizontally filtered images, regardless of whether faces were lit from above or the side. But this relationship reversed for faces lit from below. This mirrored the disproportionate changes that lighting from below, as opposed to above or the side, had on image structure visible through horizontal filtering. Overall, our data are consistent with facial recognition relying disproportionately on horizontal image structure, which would be functionally adaptive in natural conditions, wherein lighting is typically from above, or from the side, but very rarely from below.

- **Rapid recognition of unseen objects in natural scenes: Does your brain know what you didn't see?**
  W Zhu[1], J Drewes[2], Y Li[1], F Yang, X Du[3], K R Gegenfurtner[4] ([1]Kunming Institute of Zoology, Yunnan University, China; [2]Centre for Vision Research, York University, ON, Canada; [3]Yunnan University, China; [4]Abteilung Allgemeine Psychologie, Justus-Liebig Universität Giessen, Germany; e-mail: zhuweina.cn@gmail.com)

The visual system has a remarkable capability to extract categorical information from complex natural scenes (Thorpe, Fize, & Marlot, 1996). However, it is not clear whether rapid object recognition needs awareness. We recorded event-related potentials (ERPs) during a continuous flashed suppression paradigm (CFS) (Tsuchiya & Koch, 2005), in which the luminance and contrast were controlled to ensured around half of the images were seen by our subjects. In experiment 1, both animal and non-animal images were shown 500ms, and subjects were required to perform target (animal) detection: Did they see animal or non-animal images? ERP results showed animal images induced bigger amplitudes than non-animal images on "seen" condition, but smaller amplitudes than non-animal images on "unseen" condition ($F(1,75)=4.78$, $p=0.032$) In experiment 2, non-animal images were replaced with vehicle images, and subjects needed to categorize: Did they see animal or vehicle images? As in experiment 1, animal images induced bigger amplitudes than vehicle images on "seen" condition, but smaller amplitudes than vehicle images on "unseen" condition ($F(1,75)=21.7$, $p<0.001$). Our results indicate that even in the "unseen" condition, the brain responds differently on animal and non-animal/vehicle images and the rapid processing of animal images might differ in conscious and unconscious conditions.

- **Two stages in the time-course of natural scene gist perception**
  I Groen[1], S Ghebreab[2], V Lamme[1], H Scholte[1] ([1]Cognitive Neuroscience Group, University of Amsterdam, Netherlands; [2]Intelligent Systems Lab, University of Amsterdam, Netherlands; e-mail: i.i.a.groen@uva.nl)

The ability of the visual system to process natural images at remarkable speed may be mediated by a global "gist" percept. It is unclear, however, 1) how gist is computed by the visual system and 2) when and under what circumstances it is extracted. We addressed these questions using regression of single-trial EEG on scene statistics. Subjects judged one type of gist, "naturalness", for a large set of natural images. Using a neurophysiologically plausible contrast filtering model, we derived two statistical parameters for each scene: contrast energy and spatial coherence. Behaviorally, contrast energy correlated with reaction times, whereas spatial coherence correlated with perceived naturalness. In EEG, contrast energy and spatial coherence predicted differences between single-trial event-related potentials (sERPs) both early (90-150 ms) and later (> 200 ms) in time. In a follow-up experiment where we manipulated task relevance, early effects on sERP amplitude persisted when an orthogonal task was performed, whereas late effects were present only when gist categorization was required. These results suggest that scene gist 1) can be derived from responses to local contrast, for example present in LGN/V1 and 2) is computed bottom-up but can be selectively 'read out' if relevant for the task at hand.

- **Tracking temporal and spatial dynamics of visual object recognition with combined MEG and fMRI**
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The emergence of modern imaging techniques has led to considerable progress in characterizing the spatial and temporal processes of where and when course object recognition happens in the brain. Even though studies have often produced corroborating results, merging findings across methods remains challenging, because of differences in data types, sensitivities, and experimental paradigms. To leverage the spatial and temporal resolution of different imaging techniques, we measured brain responses to 92 different object images with fMRI and MEG, and combined data from these modalities using a common similarity space. The results provide new knowledge on two fundamental questions of object processing: 1) What is the time course of object processing at different levels of categorization? Multivariate analysis of MEG data shows that human brain responses can be decoded for a large set of objects, distinguishing in time between individual, basic and superordinate level of categorization (animate/inanimate, faces/bodes). 2) What is the relation between spatially and temporally resolved brain responses in a content-sensitive manner? We show a correspondence between early MEG and fMRI responses in early visual areas, and later MEG responses and fMRI in inferior-temporal (IT) cortex.

- **Ketamine changes the neural representation of object recognition**
  A M van Loon[1], H Scholte[1], J J Fahrenfort[2], B van der Velde[3], P B Lirk[4], N C Vulink[5], M W Hollmann[4], V Lamme[1] ([1]Cognitive Neuroscience Group, University of Amsterdam, Netherlands; [2]Experimental Psychology, Utrecht University - Helmholtz Institute, Netherlands; [3]Cognitive Science Center Amsterdam, University of Amsterdam, Netherlands; [4]Department of Anesthesiology, Academic Medical Center Amsterdam, Netherlands; [5]Academic Medical Hospital Amsterdam, Netherlands; e-mail: anouk.vanloon@gmail.com)

What does recognition of an object do to its representation in the brain? Previous research demonstrated that recognition alters the spatial patterns of fMRI activation even in early visual cortex (Hsieh et al. 2009). This process is thought to depend on feedback from higher-level areas to early visual areas. In turn, feedback activity is suggested to rely on the NMDA-receptor. To investigate the role of feedback in the effect of recognition, we administered either Ketamine, an NMDA-receptor antagonist, or a placebo to participants. Participants viewed Mooney images that were initially unrecognizable and later recognizable and grayscale photo versions of the same images. We used representational dissimilarity matrixes (RDM) to investigate how the spatial patterns of fMRI activation changed with recognition. Preliminary data suggests that the neural patterns of recognized Mooney images more strongly resemble neural patterns of the photographic images than of same Mooney images when not recognized. This effect was observed both in early visual areas and in object related areas. Ketamine reduced these effects of recognition in early visual areas. This suggests that reduction of feedback by Ketamine counteracts the effect of object recognition in early visual areas, or even that feedback is necessary for recognition to occur.

TALKS : NEURAL INFORMATION PROCESSING

- **Retinal receptive fields: balancing information transmission and metabolic cost**
  B Vincent[1], R Baddeley[2] ([1]School of Psychology, University of Dundee, United Kingdom; [2]School of Experimental Psychology, University of Bristol, United Kingdom; e-mail: b.t.vincent@dundee.ac.uk)

The spatio-chromatic receptive field properties of retinal ganglion cells are well characterised, but why are they this way? Due to the high level of spatial and chromatic correlations between cone responses, direct transmission of their outputs would be an inefficient use of limited optic nerve bandwidth. It has been known for some time that luminance, blue/yellow- and red/green-opponent channels are effective at reducing this inefficiency, but this only accounts for chromatic (not spatial) aspects of retinal receptive fields. We applied statistical compression methods to a large dataset of human cone-calibrated images from a Kibali rainforest. We show that the chromatic and spatial coding can be understood as maximising information transmission while minimising metabolic costs incurred. We find i) large metabolic savings can be made for little loss of performance; ii) there is a point of optimal efficiency; and iii) at this optima, the system self organises into three spatio-chromatic opponent channels with properties closely

matching those observed experimentally. In summary, the major retinal receptive field properties can be understood as being matched to the statistics of the natural environment, but only when the metabolic expenditure and information transmission are considered in conjunction.

- **Early Visual Cortex Assigns Border Ownership in Natural Scenes According to Image Context**
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Discerning objects from their backgrounds is a fundamental process of vision. A neural correlate is coding of border ownership in early visual cortex [Zhou et al, 2000, J. Neuroscience, 20(17), 6594-6611]. When stimulated with the contour of a figure, neurons with this correlate respond more strongly when the figure is on one side of their receptive field (the "preferred" side) versus the other. So far, border ownership coding has only been shown with simple displays of geometric shapes (e.g., squares). Here we studied border ownership coding with static images of natural scenes, using microelectrodes to record from isolated neurons in V1 and V2 of macaques. We found that subsets of V1 and V2 neurons indeed code for border ownership in complex natural scenes. Decomposition of local and context influences showed that the context-based border ownership signals correlated with those for the (locally ambiguous) edge of a square, but were weaker. We used stimuli with intermediate complexity along several dimensions to measure the relative influences of object shape, occlusion between objects, texture and color contrast to determine how they contribute to the border ownership signal strength. The signal decreased with complexity along all dimensions, especially with shape, occlusion and texture.

- **Blindsight: insights from neuronal responses in macaque V4 after V1 injury**
  J Schmiedt[1], A Peters[2], R Saunders[2], A Maier[3], D Leopold[2], M Schmid[1] ([1]Schmid Lab, Ernst Strüngmann Institute (ESI), Germany; [2]Cognitive Neurophysiology and Imaging, National Institute of Mental Health, MD, United States; [3]Department of Psychology, Vanderbilt University, TN, United States; e-mail: joscha.schmiedt@esi-frankfurt.de)

Patients with V1 lesions can retain a remarkable capacity for detecting visual stimuli while their perceptual visual experience is lost (“blindsight”). The question to what extent ventral-stream area V4 participates in blindsight by processing V1-independent information has so far remained controversial: Temporary cooling of macaque V1 virtually abolished neuronal activity in V4 (Girard et al., 1991, Neuroreport, 2, 81-84). In contrast, weak yet reliable fMRI responses were elicited by visual stimulation in the lesion-affected part of the visual field (scotoma) in monkeys with permanent V1 injury (Schmid et al, 2010, Nature, 466, 373-377). Here, using chronically implanted intracortical electrode arrays, we recorded neural activity in V4 before and after targeted V1 aspiration lesions. Following the V1 lesion, most V4 sites ceased to respond to visual stimulation in the scotoma. Nevertheless, a minority of sites showed weak but significant multi-unit responses to visual stimuli presented in the scotoma and exhibited motion-sensitivity. Local field potential analysis revealed power decreases in the gamma and increases in the beta range, possibly reflecting changes in feedforward and feedback signaling. In conclusion, our results indicate a V4 contribution to motion detection in blindsight that may be mediated by unmasking of motion-related processes.

- **Selective synchronization explains transfer characteristics of attention-dependent routing for broad-band flicker signals to monkey area V4**
  I Grothe[1], D Rotermund[2], S D Neitzel[3], S Mandon[3], U A Ernst[2], A K Kreiter[3], K Pawelzik[2] ([1]Fries lab, Ernst Strüngmann Institute (ESI), Germany; [2]Institute for Theoretical Physics, University of Bremen, Germany; [3]Institute for Brain Research, University of Bremen, Germany; e-mail: udo@neuro.uni-bremen.de)

Neurons with large receptive fields (RFs) receive inputs representing multiple stimuli and hence require a selection mechanism for processing the relevant signal. Here, we investigate attentional gating of temporally varying visual signals to neurons in areas V1 and V4, and whether differences in synchronization between V4 neurons and their V1 afferent inputs can quantitatively explain selection of the attended stimulus for further processing. To test experimentally whether a local group of neurons can switch processing between different parts of their synaptic inputs, we established a new experimental paradigm. We superimposed behaviorally irrelevant broad-band contrast modulations on two visual objects, both placed within the same V4 RF, while monkeys tracked the changing shape of the cued object. We used a normalized spectral coherence measure to simultaneously characterize the transmission

of the superimposed components towards local field potentials recorded in areas V1 and V4. We found strong attention-dependent gating of the visual signals towards V4. Using a minimal model implementing routing by coherence we characterized gating capabilities and transfer characteristics of this mechanism for signals modulated as in the experiment. The model reproduces the experimental findings in detail, supporting gamma-band synchronization as a mechanism subserving gating by attention.

- **Representation of Stereoscopic Depth in Pooled Responses of Macaque V4 Neurons**
  M Abdolrahmani[1], T Doi[2], H M Shiozaki[3], I Fujita[1] ([1]Frontier Biosciences School, Lab for Cognitive Neurosciences, Osaka University, Japan; [2]Department of Neuroscience, University of Pennsylvania, PA, United States; [3]RIKEN Brain Science Institute, Japan; e-mail: m.abd.ac@gmail.com)

Stereoscopic depth perception is as vivid for half-matched random dot stereograms (i.e. RDSs with zero binocular correlation) as for correlated RDSs [Doi et al, 2011, J. Vision, 11(3):1, 1–16]. We studied the underlying neural mechanisms by recording single-neuron responses of macaque visual area V4, which attenuates disparity selectivity for anti-correlated RDSs [Tanabe et al, 2004, J. Neuroscience, 24(37), 8170–8180]. Binocular disparity and the level of anti-correlation (% of contrast reversed dots) were varied across trials while monkeys performed a fixation task. Half the tested (51/103) cells were significantly disparity selective for cRDSs. Slight anti-correlation (35%) markedly decreased the amplitude of disparity tuning curves. The phase (shape) of the tuning curves, however, did not change when anti-correlation was applied up to half the dots (<50%). In contrast, the phase shifted unpredictably across V4 neurons as anti-correlation became stronger (>50%). Therefore, pooling responses across cells may account for depth perception. For instance, the pooled responses can signal disparity for half-matched RDSs (50%), because the shape of attenuated individual tuning is consistent within a pool. We suggest that neurons in downstream areas that pool V4 disparity-selective responses might be a direct correlate of binocular depth for any level of correlation between left and right images.

- **Monkey area MT response latencies are shaped by attention and correlate with reaction time**
  F O Galashan, H C Saßen, A K Kreiter, D Wegener (Theoretical Neurobiology, Institute for Brain Research, University of Bremen, Germany; e-mail: wegener@brain.uni-bremen.de)

Adaptive behavior in dynamic environments relies on the ability to reliably encode relevant visual information and to quickly transform this into appropriate motor actions. Attention is known to modulate stimulus representations in early visual cortex and to improve behavioral performance, but the neuronal mechanisms by which attention-dependent modulations in visual cortex are linked to behavior are not well understood. One frequently discussed hypothesis is a relation between behavioral reaction times and neuronal response latencies, although previous single-cell studies failed to provide experimental evidence. We used a speed-change detection paradigm and single-unit recordings in monkey motion-sensitive area MT and we introduced some presumably important methodological and analytical adaptations to investigate this issue in detail. Our data provide support for a marked influence of attention on neuronal latencies in response to the stimulus event to which the animals were required to respond. Furthermore, relating neuronal response patterns to the animals' perceptual performance revealed a strong correlation between latencies and behavioral reaction times. Various control conditions and analyses verified these results. The data also show that neuronal firing rates, even though being modulated by attention, do not relate to behavioral performance, whereas neuronal response variability prior to the behaviorally relevant event does.

TALKS : PERCEPTUAL LEARNING

- **Perceptual Learning Leads to Category Selectivity 100ms after Stimulus Onset**
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Categorizing visual input is one of the most essential challenges faced by our visual system. Despite its importance, however, the debate on the cortical origin and the timing of category-specific effects remains unsettled. This is in part due to potential low-level confounds arising from the use of naturally occurring visual categories. Here we circumvent such problems by combining extensive training of two artificial visual categories with EEG and MEG adaptation. This approach allowed us to investigate category effects arising purely from category training, while ruling out alternative explanations based

on low-level stimulus properties. Prior to category training, no differences in the visually evoked potentials were observed, demonstrating a successful control for low-level stimulus properties. After training, however, we find significant category-selective differences in the early P100 (EEG, peak latency 108ms, $p<0.05$ two-tailed t-test) and M100 (MEG, peak latency 118ms, $p<0.05$ two-tailed t-test) components. Importantly, significant differences were only found for correct trials and not for incorrect ones, illustrating the behavioral relevance of the investigated process. The timing and topography of the found effects render feedback from frontal areas unlikely and suggest rather that the origin of category selective representations is in the ventral stream.

- **Orientation perceptual learning may be orientation concept learning**
  C Yu (Department of Psychology, Peking University, China; e-mail: yucong@pku.edu.cn)

Where learning occurs in the brain and what is being learned are central to the understanding of perceptual learning. Previously we have used new double training and training-plus-exposure (TPE) techniques to enable perceptual learning of orientation discrimination to transfer completely to untrained retinal locations and orientations (Zhang et al., VisRes & JNeurosci, 2010a,b), indicating that orientation learning is a high-level process occurring beyond retinotopic and orientation-selective visual areas. Recently Wu Li at Beijing Normal University and I also demonstrated complete mutual transfer of perceptual learning between explicit and implicit orientation signals. Specifically, learning of discriminating implicit symmetry axis orientation, likely encoded by later visual areas, transferred completely to explicit grating orientation encoded by V1 neurons. Meanwhile, explicit grating orientation learning transferred only partially to implicit symmetry axis orientation, but the transfer became complete with additional exposure of the symmetric patterns in an irrelevant task (TPE training). The mutual complete learning transfer suggests that orientation learning is a highly abstract process that is unspecific to not only the trained retinal location and orientation, but also the stimulus physical properties and underlying neural decoders. We argue that the concept of orientation is being learned in highly abstract orientation perceptual learning.

- **The reference frame of perceptual learning**
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In perceptual learning, perception improves with practice. Perceptual learning is mainly investigated with retinotopic paradigms. Here, we show evidence for perceptual learning within a non-retinotopic frame of reference. During the training phase, we presented three disks. In the center disk, dots moved upwards with a slight tilt to the left or right. Observers indicated the tilt. Performance improved significantly by 33% on average. Before and after training, we determined performance for various "moving conditions". First, three empty disks were presented at the same location as in the training condition. Then, there was an ISI of 100ms and the disks shifted one disk position to the right (i.e., a Ternus-Pikler display), creating the impression of apparent motion. The same motion as in the training condition was presented either in the left disk, which retinotopically overlapped with the training disk, or in the center disk. The center disk overlapped with the training disk in object-centered coordinates but not in retinotopic coordinates. We found that learning transferred most strongly in the latter, non-retinotopic condition. Our results indicate a non-retinotopic, object-centered component to visual perceptual learning. We propose that perceptual learning may best be achieved after spatial invariance is reached.

- **Push-pull training reduces interocular suppression in amblyopic vision**
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Amblyopia is characterized by poor visual acuity in AE eyes and degraded stereoacuity, which can be improved through perceptual learning. Here we studied whether a push-pull training method, which reduces interocular suppression, could further improve vision in amblyopes who have practiced >60 hours in regular perceptual learning experiments. In push-pull training, AE practiced contrast discrimination while NAE was presented with bandpass noise centered at 1/2 cutoff frequency. A staircase measured the tolerable noise contrast (TNC) in NAE for successful contrast discrimination in AE. In pre- and post-tests, AE and NAE stimuli were switched to measure TNC in AE. Interocular suppression was the difference between AE and NAE TNCs. Push-pull training (ten 2-hr sessions) increased TNC in NAE, and reduced interocular suppression by 60%. This reduction didn't transfer to

an orthogonal orientation or a tumbling-E task. Training also improved stereoacuity by 25%, on top of the 54.7% improvement from previous perceptual learning, but had no further impact on AE visual acuity. Push-pull training thus reduces interocular suppression in an orientation and task specific manner in well-practiced amblyopes, which further improves stereoacuity, but not AE visual acuity. The task specificity suggests the involvement of high-level processes.

◆ **Prism Adaptation: Why is it so difficult to understand?**
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When we put on prisms shifting the visual world laterally, we usually need only a few movements to almost perfectly adapt to them. After removing the prisms, our movements deviate initially in the opposite direction, a nice after-effect lasting almost as long as the adaptation process. All that seems to be required for adaptation is a lateral shift, in the nervous system, neutralizing the optic shift induced by the prisms. But prism adaptation, contrary to intuition, is a purely proprioceptive effect: the proprioceptive signals of the eye, neck or arm have to be adapted, while the visual input stays identical, due to compensatory eye movements. We measured these three adaptations separately for the subjective straight ahead of eyes, head, and arm without visual feedback (in the dark). It turns out that the relative amount of adaptation depends on various factors such as the amount of visual feedback (full arm movement seen versus feedback only at endpoint of movement), presence of additional acoustic feedback, target position in the visual field, angle between arm and trunk, type of movement, and even inter-individual differences. These dependencies explain differences in reported results, for example some studies reporting transfer between arms while others do not.

◆ **When perceptual learning can transfer to practical improvements of visual functions**
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Transfer and generalization of the trained task to other visual functions and locations is an important key for understanding the neural mechanisms underlying perceptual learning. Here we report results obtained from two different groups of subjects that were trained on contrast detection of Gabor targets under spatial and temporal masking conditions, targeting improvement of collinear facilitation and temporal processing. The group of presbyopes (aging eye, average age 51 years) was trained only on the foveal location from 40 cm using two temporal alternative forced choices. A second young group was trained on the fovea and the periphery simultaneously (center, right, and left) using the Yes/No method. Training improved lateral interactions (increased facilitation and diminished the lateral suppression when it exists) and many visual tasks and applications such as contrast sensitivity, visual acuity, backward masking, crowding, reaction time, stereo acuity, reading speed, and viewing complex images (camouflages). The transfer of learning to different visual functions indicates that the improvement can be generalized by practice on combined spatial and temporal masking tasks. The transfer between different visual tasks can be achieved by improving the processing speed, which enables more efficient processing of many visual functions.

POSTERS : MULTISENSORY PROCESSING AND HAPTICS

◆ **Interference on memory between olfactory stimulus and visual stimulus with time-interval**
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Many studies have reported on Cross-modal (or Multi-modal) interaction. We tried to resolve the integration mechanism of vision and olfaction on memory. We gave subjects visual stimulus presentation and then (within very short time interval: 0-300 msec) olfactory stimulus presentation. This was the V(isual)-O(lfactory) condition, we did O-V condition too. The visual stimulus was a colored square and the olfactory stimulus a scent of food. Subjects were required to memorize the presented color and scent. About 1 minute later, there were two recall tests: 1: Following presentation of gradual color patches and a scent, subjects were required to recall and identify the memorized color. 2: Following presentation of scents one after another and a color, subjects were required to recall and identify the memorized scent. We found that subject's memory of color is interfered by olfactory stimuli when presented within a short

time interval. We also found that this interference is influenced by the interval time, but the relation is not linear.

◆ **Effects of color on perceived temperature**

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Although concepts of associating color with temperature (eg. blue is cold) has been widely applied in design, it remains unclear whether color could affect our sensations of warmth and coldness. Here we manipulated the color of an object surface and examined its effect on the perceived temperature of the object in contact. In the subjective criteria condition, the participants touched the object surface and responded whether this surface felt warm (or cold). In the objective criteria condition, the participants judged whether the surface felt warmer (or colder) than a reference. In both conditions, the temperature of the surface varied adaptively based on participants' responses to search for the warm (cold) boundary, that is the temperature at which the sensation transits from warm (cold) to neutral. We found that the warm boundary of a blue surface was significantly lower than that of a red surface in the subjective criteria condition, while such effect was not found in the objective criteria condition. Our results indicated that the perceived temperature of an object can be affected by its color. Like size-weight illusion, this effect might result from perceptual rescaling based on prior expectations, and it would diminish when an external reference was provided.

◆ **Effects of Color and Odor of Colored Water on Predicted Palatability**

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We conducted three types of experiment: a visual experiment, an olfactory experiment and a visual-olfactory experiment to reveal the effects of color and odor on predicted palatability of soft drinks. We prepared six kinds of colored water: yellow, orange, red, purple, blue and green, by dissolving artificial colorants with mineral water. We also prepared four kinds of essence: lemon, apple, strawberry and mint. The colored water was in a PET bottle, and each essence was put on a smelling-strip on the underside of the bottle cap. In the visual experiment, subjects observed one of the colored waters without any olfactory stimulus. In the olfactory experiment, they observed non-colored water (freshwater) and smelled the underside of the cap. In the visual-olfactory experiment, they observed one of the colored waters while smelling an essence. Subjects evaluated the "predicted sweetness","predicted sourness", "predicted bitterness", and "predicted palatability" in each experiment. They were twenty females and in their twenties. As a result, strong cross-modal effects were found, such as palatability was higher when the image of the odor matched the color. The contribution ratios of olfaction to vision were 4.61 in sweetness, 1.91 in sourness, 1.98 in bitterness and 1.24 in palatability, respectively.

◆ **Facial Identification in Observers with Colour-Grapheme Synaesthesia**

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Synaesthesia between colours and graphemes is often reported as one of the most common forms cross modal perception [Colizolo et al, 2012, PLoS ONE, 7(6), e39799]. In this particular synesthetic sub-type the perception of a letterform is followed by an additional experience of a colour quality. Both colour [McKeefry and Zeki, 1997, Brain, 120(12), 2229–2242] and visual word forms [McCandliss et al, 2003, Trends in Cognitive Sciences, 7(7), 293–299] have previously been linked to the fusiform gyrus. By being neighbouring functions speculations of cross wiring between the areas have been suggested as an explanation of a neural substrate of synaesthesia. The present study does not have a strong point on this view. However, as the fusiform gyrus also have been proposed to play a crucial role in the processing of facial features for identification [e.g. Kanwisher et al, 1997, The Journal of Neuroscience, 17(11), 4302–4311], increased colour-word form representations in observers with colour-grapheme synaesthesia may affect facial identification in people with synaesthesia. This study investigates the ability to process facial features for identification in observers with colour-grapheme synaesthesia. Preliminary data suggest that observers with colour-grapheme synaesthesia have a decreased ability to identify other people from facial cues.

◆ **Teasing apart the effects of synesthetic congruency on temporal order judgements**

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The temporal ventriloquism effect is observed when an auditory stimulus presented in temporal proximity to a visual stimulus changes the perceived temporal onset of the visual stimulus. Recent studies have found that pitch-size synesthetic congruency may be important factor. According to these, when congruent tones are presented, one before and one after two temporally- and spatially-separated visual disks, temporal order judgements of the disks are easier due to binding of the audio-visual pairs. If the tones and disks are incongruent, it is harder to distinguish this temporal order. In the present study, we focus on pitch-contrast synesthetic congruency (e.g., high tones and bright disks; low tones and dark disks). We demonstrate that the instruction provided to participants has a significant impact on the outcome of the data, which explains inconsistencies in the results of previous studies. We also demonstrate better temporal order judgements for incongruent trials at shorter visual-visual intervals, changing to better judgements for congruent trials at longer intervals. This suggests an initial contrast effect, whereby the visual and auditory systems first optimize processing of the individual features within each modality, followed by an assimilation effect, when integration occurs and the system becomes more sensitive to audiovisual congruencies.

◆ **The effects of phonological and semantic information on color perception in**

6 **grapheme-color synesthesia**

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The experience of synesthetic color is the same even if input stimuli are different. Similar synesthetic colors can be elicited by similar features of characters, such as morphological forms and phonological information in grapheme-color synesthesia [Asano & Yokosawa, 2011, Consciousness and Cognition, 20(4), 1816–1823; Witthoft & Winawer, 2006, Cortex, 42(2), 175–183], and by word meanings in word-color synesthesia [Callejas et al., 2007, Brain research, 1127(1), 99-107; Ward, 2004, Cognitive Neuropsychology, 21(7), 761-772]. Previous studies have mostly examined synesthetic colors elicited by morphological forms and phonological information because each phonographic character does not contain a meaning. We investigated whether graphemes in an ideogram could be affected by meaning and thereby elicit synesthetic color. In Experiment 1, phonological information in the ideogram induced synesthetic colors similar to those induced by a phonogram. In Experiment 2, an ideographic character was strongly influenced by the relationship between phonemic and semantic information. The results reveal that (1) synesthetic colors elicited by an ideogram were equivalent to the meaning of the stimuli, even though they had the same phonological information, and (2) each ideographic character of the color name evoked the same synesthetic color as the color name. Thus, we conclude that grapheme-color synesthesia is a phenomenon in which multiple perceptual and cognitive factors are involved. These results show that the causes of synesthetic colors in grapheme-color synesthesia are strongly influenced by the letter types.

◆ **Brain oscillations during perceptual closure in grapheme-colour synaesthetes**

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In grapheme-colour synaesthetes, letters and numbers evoke colour. Synaesthesia may involve hyperbinding of colour and graphemes; we investigated whether this alters the threshold of conscious perception. At the neural level, binding processes are associated with increased synchronization between different features. Using magnetoencephalography and a visual closure task we investigated the impact of synaesthesia on the threshold of awareness. Twenty synaesthetes and 20 controls were presented with synaesthesia-inducing (letters and numbers) and non-inducing stimuli (symbols). Stimuli were embedded in a coloured noise background, which was congruent with the synaesthetic colour or neutral (symbols). The amount of noise was parametrically varied and the visibility threshold of the embedded grapheme was determined by subjective visibility ratings. Both groups showed similar visibility thresholds in the symbols condition, but synaesthetes perceived more synaesthesia-inducing stimuli than controls . Synaesthetic hyperbinding may aid synaesthetes during closure. Magnetoencephalography data showed induced gamma band activity (50-70 Hz and 80-100 Hz) over occipital sensors; for letters, synaesthetes

showed increased gamma power compared to controls. Source localisation (50-70 Hz) of successfully identified graphemes revealed activity in early visual areas (V2) as well as area V4 and parietal cortex. We suggest that altered gamma activity reflects hyperbinding.

◆ **Frequencies of Hiragana, Alphabets, and Digits Correlates in Color Association: Comparison between 'Synesthetes' and 'Non-Synesthetes' in Japanese**

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Grapheme-color synesthesia means perceiving induced color automatically when viewing letters. Synesthesia is important for clarifying the relationship between sensation modalities. The purpose of this study is to investigate the features of synesthetes from a correlation between color association and frequencies of letters. We defined color association as any colors that synesthetes can perceive and non-synesthetes associate with when viewing letters. We used hiragana (Japanese phonetic characters), alphabets, and digits as stimuli. Participants (synesthetes and non-synesthetes) observed hiragana, alphabets, and digits, and were told to select a color association for each letter. We investigated correlations between color association and frequencies of letters. We found the following: (1) There was a correlation between color association and frequencies with hiragana and digits both for synesthetes and non-synesthetes. (2) There were no correlations with alphabets. (3) Commonly used letters (from a native language and digits) affected correlations regardless of whether participants were synesthetes or non-synesthetes. Therefore, it is thought that perceiving and associating color when viewing letters is automatic, and synesthetes can bring colors up in their consciousness, unlike non-synesthetes.

◆ **Auditory modulation of extra-retinal velocity signals**

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Makin et al. (2012, Acta Psychologica 129, 534-521) found that repetitive auditory click trains increased the perceived velocity of subsequent moving gratings. The current work tested whether auditory clicks selectively alter retinal or extra-retinal velocity signals. On every trial, participants listened to either a 4Hz auditory click train or a silent interval, then viewed a moving dot-target that traveled at a speed between 7.5 and 17.5 deg/s. Pursuit and fixation trials were compared, and compliance with oculomotor instructions was monitored with an eye tracker. Velocity estimates were entered with the keyboard after each trial. In our first experiment, the dot targets moved horizontally, we found that prior auditory clicks only increased subjective velocity on the pursuit trials. In our second experiment we replicated the results with vertical motion. In a third experiment, the click effect disappeared when an orthogonally orientated sine-wave grating was presented behind the pursuit target. This could be because participants based their estimates on the reliable retinal velocity signals that were caused by opponent motion of the static background. These findings provide convergent evidence that auditory clicks selectively alter extra-retinal velocity signals, and clarify the nature of the links between visual and auditory networks.

◆ **Distortion of auditory space during linear vection**

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Self-motion perception relies on integration of multiple sensory cues, especially from the vestibular and visual systems. Our previous study demonstrated that vestibular information on linear self-motion distorted auditory space perception [Teramoto et al., 2012, PLoS ONE, 7(6): e39402]. Here, in order to elucidate whether this phenomenon is contingent only on vestibular information, we investigated the effects of visual self-motion information on auditory space perception. In experiments, large-field visual motion was presented on a screen so that participants experienced either forward or backward self-acceleration (linear vection). In the meantime, a short noise burst was presented from one of the loudspeakers that were aligned parallel to the illusory self-motion direction along a wall to the left of the participants. The participants indicated in which direction the noise burst was presented, forward or backward relative to their subjective coronal plane. Results showed that the sound position aligned with the subjective coronal plane was displaced in the traveling direction for self-acceleration conditions, when comparing with that for a no-motion condition. These results suggest that self-motion information, irrespective of its origin, is crucial for this distortion of auditory space perception.

◆ **Visual and auditory stimuli capture attention in a cross-modal oddball paradigm irrespective of the attended modality**

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Does attending to one stimulus modality affect attentive processing in a different modality? Using the P300 of the event-related potential as an index of attentional allocation, we assessed the role of unimodal attention in a crossmodal auditory-visual oddball paradigm with a 2x2 design (stimuli x tasks). Stimuli were either auditory oddballs embedded among frequent visual stimuli, or vice versa. The task was either to attend to auditory stimuli or to attend to visual stimuli (whether oddball or not). Additionally, in a third stimulus sequence, oddballs were conjoint auditory-visual stimuli among randomly alternating unimodal visual and auditory stimuli. Again, the task was to either attend visual or auditory stimuli (whether unimodal or part of a conjoint stimulus). P300s to both visual and auditory oddballs were nearly independent of the task modality. This suggests that oddballs captured sufficient attention even when disattended. With either task, responses to conjoint oddballs in the third stimulus sequence were absent. Thus, despite unimodal oddballs being unaffected by a crossmodal diversion of attention, oddballs defined by conjointness of modalities are inefficient in eliciting a P300 response with either task. Both findings are symmetric with respect to the task, suggesting a common underlying principle of stimulus processing.

◆ **Effect of audio and visual distance on simultaneity perception**

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Several studies suggest that the brain can use distance cues to maintain perceptual synchrony. Here we want to separate the effect of audio and visual distance and analyze the effect of blocked presentation. Participants performed temporal order judgments of stimuli presented with several asynchronies from speakers and LEDs at 1m and 16m in a lit corridor. Distances of beeps and flashes were combined to obtain four conditions with collocated and dislocated audiovisual events. In separate sessions the four conditions were presented either interleaved or blocked. Beep distance causes transmission delay that requires stimuli to be presented earlier to appear simultaneous with flashes. Interestingly, we find that simultaneity is affected primarily when conditions are presented blocked. Flash distance causes decreased retinal size and lower stimulus energy increasing perceptual delay and requiring stimuli to be presented earlier to appear simultaneous with beeps. Simultaneity is more affected when conditions are interleaved likely because of attention and peripheral viewing. Distance of beeps and flashes influence perceived simultaneity, suggesting incomplete use of distance cues. The effects for the two modalities differ in interleaved and blocked presentation suggesting a differential effect of adaptation for the two modalities.

◆ **Auditory gap transfer modulates perception of visual apparent motion**

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Auditory gap transfer illusion refers to that when a long glide with a temporal gap in the middle crossed with a shorter, continuous glide at the temporal midpoint, the gap is perceived in the shorter pitch trajectory [Nakajima et al.2000, Perception & Psychophysics, 62,1413-1425]. Here auditory gap transfer paradigm was employed to investigate how perception of visual apparent motion is modulated with two competing glides. Ternus display was used. The Ternus display involves a multielement stimulus that can induce either ‘element motion’ or ‘group motion’, dependent on the inter-stimulus-interval between two visual frames. In Experiment 1, Ternus display was embedded in a temporal gap (100 ms) of either a long glide or a short glide. The longer glide biased the perception of visual Ternus to be more reports of "group motion" than the short glide did. In Experiment 2, a shorter continuous glide crossed the middle of a long glide with a temporal gap. The gap was perceived in the shorter glide and the percentage of reporting "group motion" was decreased as in Experiment 1. The results indicated that with competing auditory events, the salient temporal grouping of auditory events precedes and dominates in affecting perception of visual apparent motion.

◆ **Behavioural and neural correlates of audio-visual motion in depth**

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Low-level contextual factors such as visual expansion and disparity cues or auditory loudness changes mediate audio-visual integration, with enhanced neural and behavioural responses for looming compared to receding motion. The current research explores behavioural and electrophysiological responses to congruent and incongruent audio-visual motion signals in conditions where auditory level changes, visual expansion and disparity cues were manipulated. In a behavioural study participants were asked to discriminate audio motion direction whilst watching visual looming or receding 2D and 3D stimuli. Responses were faster and more accurate for congruent motion, with significantly larger response modulation when visual 3D (disparity) cues were presented compared to 2D presentation. Using electroencephalography in a second experiment, the same factorial design was employed but with a deviant trial task rather than motion discrimination. Significant effects of motion and disparity were observed before 300ms in posterior, temporal, central and frontal electrode positions, indicating a modulation of the visual evoked potentials by the presence of 3D cues at early processing stages. A significant main effect of congruence was observed at ca. 480ms post stimulus onset, in which incongruent trials were associated with increased negativity over frontal electrodes.

◆ **Multisensory Integration of Scene Perception: Semantically Congruent Soundtrack**

15 **Enhances Unconsciously Processed Visual Scene**

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We examine whether the gist of natural scenes can be extracted unconsciously and be affected by a semantically congruent soundtrack. The continuous flash suppression paradigm was used to render a visual scene (restaurant or street) invisible while participants listened to a soundtrack (background sounds recorded in a restaurant or on a street). This paradigm also has the advantage of making the audio-visual semantic relationship opaque to avoid response bias. The contrast of the visual scene was increased gradually in one eye although was masked by dynamic Mondrians in the other eye. Participants were required to respond whenever they saw anything different from the Mondrians and indicate the location of the scene (top or bottom). The released-from-suppression time of correct localization was shorter when it was accompanied by a semantically congruent soundtrack rather than by an incongruent one (Experiment 1). Semantic congruency effects were eliminated by removing critical objects (e.g., dishes or cars) and leaving only the background (Experiment 2), or by presenting only these critical objects without the background (Experiment 3). This is the first study demonstrating unconscious processing of the gist of visual scenes—which occurs when both objects and background are included—and audio-visual integration for complex scenes.

◆ **Interaction of spatial and temporal processing in the context of audio-visual synchrony**

16 **judgment and temporal-order judgment**

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While both synchrony judgment (SJ) and temporal order judgment (TOJ) have been used to characterize temporal processing of multisensory stimuli, the exact nature in which both measures differ is still a matter of debate. Quite generally however, a principal difference seems to be that SJ can be achieved by focusing only on the temporal relationship of two stimuli, whereas TOJ requires focusing on an additional stimulus dimension, like color, location, etc. in order to perform the task. On the basis of the modality appropriateness hypothesis (performance in the auditory and visual modality can benefit relatively more from temporal, and respectively, spatial cues) it can therefore be hypothesized that, by switching from an SJ-task to a spatialized TOJ-task (e.g. testing on which side a stimulus was perceived first), the visual would benefit more than the auditory modality. We therefore used a 2×2-within-participants repeated-measures-design (2 TASKS: SJ vs. TOJ, 2 MODALITIES: vision vs. audition) to test this hypothesis. We found a significant ($p=0.02$) effect for MODALITY and significant ($p<0.01$) interaction.

Duncan's post-hoc test confirmed that the visual modality benefitted from the switching to a spatialized TOJ task while performance in the auditory modality deteriorated. An additional electrophysiological experiment further supported this hypothesis.

◆ **Crossmodal cueing effects on multisensory integration**

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It is well known that visual spatial cues affect performance in signal detection, that is, targets at correctly cued locations are detected faster, on average, than incorrectly cued targets [Posner, 1980, Quarterly Journal of Experimental Psychology, 32, 3–25]. In contrast, no significant effects were found with peripheral visual cues in auditory target detection [Driver & Spence, 1998, Trends in Cognitive Science, 2, 254–262]. We revisited these findings with two experiments (n = 18 participants) in which central and peripheral visual cues were presented together with audiovisual redundant targets presented with onset asynchrony. We replicated the results of the original spatial cueing paradigm as well as those with crossmodal cues. The Diffusion Superposition Model [Schwarz, 1994, Journal of Mathematical Psychology, 38, 504–520] can explain response times for redundant targets and we found that although response times to auditory targets were much less affected by visual cues than those to visual targets, this result can be readily explained by the model, assuming modality invariant cueing effects. We provide explanations for this apparent paradox within the diffusion superposition framework.

◆ **Accurate and precise parameter recovery of the TWIN model for multi-sensory reaction**

18 **time effects**

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In multisensory settings such as the focused attention paradigm (FAP), subjects are instructed to respond to stimuli of the target modality only, yet reaction times are shorter if an unattended stimulus is presented with a certain temporal offset. The "time window of integration" (TWIN) model has been successful in predicting these observed cross-modal reaction time effects. It proposes that all the initially unimodal information must arrive at the point of integration within a certain time window in order to be integrated and initiate the observed reaction time reductions. Here, we conducted a parameter recovery study of the basic TWIN model with five parameters for the duration of the visual and acoustic unimodal and the integrated second stage, the length of the time window, and the size of the effect. Parameter estimations were evaluated in terms of accuracy and precision. Results show that deviations from the true value are of only insignificant size for all parameters. Especially duration parameters for the unimodal stage of the focused stimulus and the integrated second stage are both highly accurate and precise, in fact to such an extent that they match statistics of single cell recordings.

◆ **Individual variations in visual control of posture predict vection**

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Visually-induced illusions of self-motion (vection) can be compelling for some people, but there are large individual variations in the strength of these illusions. Do these variations depend, at least in part, on the extent to which people rely on vision to control their postural stability? Using a Bertec balance plate in a brightly-lit room, we measured excursions of the centre of foot pressure (CoP) over a 60-second period with eyes open and with eyes closed, for 13 participants. Subsequently, we collected vection strength ratings for large optic flow displays while seated, using both verbal ratings and online throttle measures. We also collected measures of postural sway (changes in anterior-posterior CoP) in response to the same stimuli while standing on the plate. The magnitude of standing sway in response to expanding optic flow (in comparison to blank fixation periods) was predictive of both verbal and throttle measures for seated vection. In addition, the ratio between eyes-open and eyes-closed CoP excursions (using the area of postural sway) also significantly predicted seated vection for both measures. Interestingly, these relationships were weaker for contracting optic flow displays, though these produced both stronger vection and more sway.

◆ **Illusory motion causes postural sway**

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Visual stimuli simulating self-motion through the environment can induce potent postural adjustments in observers. This suggests a rather direct, stimulus-driven, mechanism subserving these visuo-vestibular interactions. Here we examine whether visual-motion induced sway can also be generated by an internal representation of visual motion, as apparent in the motion-aftereffect or whether any induced sway after adaptation is the result of a postural-aftereffect. We presented a random-pixel-array (87° x 56°) translating at 3 deg/s leftwards or rightwards during adaptation. A static version of the random-pixel-array or a black screen was used as test pattern. The latter pattern did not generate a motion-aftereffect and was used to determine the sway caused by the postural-aftereffect. Observers, standing on a force plate collecting posturograhic data, initially received 40s adaptation, followed by 20s top-up adaptation epochs, interleaved by 14s test pattern epochs. Results show that a static test pattern induced more sway than a black test pattern. This suggests that the sway induced by the static test pattern is the result of the perceived motion in the motion-aftereffect and not a mere result of a postural-aftereffect. This is evidence that visuo-vestibular interactions observed in visual motion induced sway are the result of the actual visual experience.

◆ **Eye movements modulate self-motion perception**

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As we move through the world we usually move our eyes to maintain fixation on objects of interest. However the consequences of these fixation eye movements for self-motion perception remain unclear. To investigate this question, we compared perceived displacement across world-fixed, body-fixed and free fixation conditions. Participants were translated laterally in two intervals and had to determine whether the second interval was farther or shorter than the first. Movement time was always 0.8s, and the reference movement was always 10cm. Fixation condition (world, body or free) was randomized across trials. Displacement was underestimated in the body-fixed condition, in which the eyes remain stationary, compared to the world-fixed condition, in which the observer must move the eyes to maintain fixation. Furthermore, perceived displacement was greater with near (50 cm) than with far (2 m) world-fixed targets, consistent with the increased version eye movement required to maintain near versus far fixation. Overall, larger eye movements were associated with larger perceived displacements. This interaction is reminiscent of eye position modulations seen in self-motion processing areas like MST.

◆ **No sex differences in vection**

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Although sex differences in spatial cognition have been reported by a number of studies, few studies have investigated possible sex differences in the aspects of basic human perception that support spatial cognition. In this study, we thus focused on investigating possible sex differences in a particular aspect of spatial perception: vection. We measured illusory self-motion perception (vection) strength for 24 males and 22 females. We presented expanding optic flow and induced forward vection for 30 seconds. Optic flow displays (72° × 57°; presented for 30 s) consisted of 16,000 randomly positioned dots. The global dot motion simulated forward-moving self-motion (16 m/s). Participants were asked to press a button when they perceived forward-moving self-motion. Participants rated subjective vection strength using a 101-point rating scale ranging from 0 (no vection) to 100 (very strong vection) after each trial. There was no significant difference in the obtained vection strengths between males and females ($t(43.145)=1.15$, $p=0.25$), indicating no sex difference in vection. This result suggests that there are no sex differences in spatial perception. The current finding of no sex differences in spatial perception with respect to vection does not support previously reported sex differences in spatial cognition.

◆ **The contribution of the vibrotactile stimulation to the mirror illusion**

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When people view their left hand in a mirror positioned along the midsagittal plane while moving both hands synchronously, the hand in the mirror visually captures the right hand self-sensation. We visualized the critical distance between the real and the reflected hand to evoke this illusion by utilizing a position sensor and machine learning. The estimated offset area was a 10×20 ellipse around the reflected hand's position; we tested the effect of the efferent signal on the illusion based on this estimate. Vibro-tactile stimulation was used at the fingertip to evoke force-like sensation and apparent finger movement as in the Pinocchio illusion [Mizuno et al, 2010, The Virtual Reality Society of Japan, 15(4), 595-601]. The mirror illusion was still observed with apparent finger movements. When this stimulation was conducted synchronously with actual movements, 3 out of 12 participants felt the illusion almost anywhere within their reach. Whether these findings derive from the terminal vibration or from other factors (e.g. the apparent finger movement sensation) is unclear. However, the efferent copy is likely just one type of multimodal feedback that generates physical sensation; subjective matching with more than two modalities can be a benefit to capture self-body sensation.

◆ **Gaze behaviour change around a 317-ms visual feedback delay during a simple**

24 **block-copying task**

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The temporal delay between action and visual feedback is critical for self-body sensation regarding our natural body and any form of human-machine interaction. We examine how human behaviour and self-body usability changes when haptic feedback and visual feedback lose their spatiotemporal match, and how humans cope with this problem under a naturalistic situation. Participants performed a simple block-copying task "through" a delayed video image on a CRT display [Pelz et al, 2001, Experimental Brain Research, 139, 266-277]. Sense of ownership and agency were investigated to examine the usability and controllability of the hand shown on a visual display, as well as the visual image itself. As the delay increased, the reaction time increased. The distribution of fixation durations as well as questionnaire data revealed several qualitative changes before and after a 317-ms delay. These results suggest that participants changed their task strategy around this border value. Whether the change was due to the visual and tactile asynchrony around the gaze position, change in self-body sensation, or other factors is uncertain. Participants probably changed their strategy around this value to determine where to allocate attention: the hand in the display or their own hand. Their gaze behaviour reflected this change.

◆ **Mental rotation in visual and haptic object comparison**

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We applied the original Shepard and Metzler mental rotation task (1971) in an active touch setting. Two objects, given simultaneously to the participants, were to be classified as identical or mirrored by both haptic and visual exploration. Participants also performed a classical visual mental rotation task. The question was whether the linear increase in RT as a function of angular rotation, typically found for the visual task, will also be found in active touch. Both tasks include perceptual, memory and motor components. The notion of functional equivalence does not sufficiently explain the interlocked mechanisms of sensorimotor control and perceptual processes. If angular disparity does not only influence RT but also gaze frequency, individual slopes of different indicators should show a high degree of correspondence across tasks. Our approach considers the role of the visual and haptic working memory and emphasizes the function of anticipatory control of actions. Within-subject comparisons of the frequencies of movements in the visual and haptic information pick-up elucidate the importance of internal sensorimotor models for the process of mental rotation. Results show the importance of considering the particular influences of different memory skills in mental rotation.

◆ **Visual and Haptic Spaces of Materials**

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Both the visual and the haptic sense play an important role in the everyday perception of materials. How both senses compare in such tasks has received little attention so far. Previously, Bergmann Tiest & Kappers (2007, Acta Psychologica, 124, 177-189) found a good correspondence between the visual and haptic sense in roughness perception. Here, we set out to investigate the degree of correspondence between the visual and the haptic representations for a large variety of material properties (roughness, elasticity, colorfulness, texture, hardness, three-dimensionality, glossiness, friction, orderliness, temperature) for different material classes (plastic, paper, fabric, fur & leather, stone, metal, wood). We asked subjects to categorize and rate 84 real material samples visually and haptically in separate sessions. Categorization performance was considerably worse in the haptic condition than visually. However, ratings correlated highly between the visual and the haptic modality (average r=0.62 across materials) and showed a similar organization in a principal component analysis. We conclude that even though both senses seem to be able to form similar representations of material classes, the information in the haptic sense alone might not be quite fine-grained and rich enough for perfect material recognition.

◆ **Haptic integration of distance and curvature**

27 V Panday, W Bergmann Tiest, A Kappers (Faculty of Human Movement Sciences, VU University Amsterdam, Netherlands; e-mail: v.panday@vu.nl)

We investigated how curvature and distance between the fingers are combined in haptic discrimination of shapes. In this experiment, we asked subjects to explore three types of objects between their thumb and index finger. In the first condition, the objects consisted of two flat surfaces that only differed in the distance between the surfaces. In the second condition, the objects consisted of two curved surfaces with the same maximum distance between the surfaces. These objects differed only in curvature. In the third condition, the objects differed in both distance and curvature, in such a way that they formed cylinders with a circular cross-section. In each condition, subjects had to discriminate between two objects that differed in either distance, curvature or both. We found that fraction correct for both condition 1 (only distance) and condition 2 (only curvature) were significantly lower than for condition 3 (both distance and curvature). There was no significant difference between conditions 1 and 2. This indicates that when curvature and distance are combined, discrimination improves.

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◆ **Contextual modulation in haptic vernier offset discrimination**

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In order to efficiently process information from the environment, the perceptual system has to organize this information across space and time. For example, perceptual grouping has been shown to be an organizational principle of both the visual and auditory system. Despite the prominent importance of integrating spatial and temporal information in the haptic domain, perceptual grouping has not been studied to a large extent in haptics. In the current study, we used a haptic vernier offset discrimination task to investigate whether, in spite of the apparent differences between the modalities, perceptual grouping in haptics and vision are similar. Participants discriminated the offset of a haptic vernier. The vernier was flanked by different flanker configurations: no flankers, single flankers, multiple flankers, boxes and single perpendicular lines. Secondly, we varied the width of the flankers. Our results show a clear effect of flankers: performance was much better when the vernier was presented alone compared to when it was presented with flankers. Moreover, error rates were higher when the flankers had the same size as the vernier itself. These results are similar to those found in visual vernier offset discrimination, which may suggest similar underlying grouping mechanisms for vision and haptics.

◆ **Haptic size aftereffect is shape dependent**

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Recently, we showed a strong haptic size aftereffect by means of a size bisection task: after adaptation to a large sphere, subsequently grasped smaller test spheres feel even smaller, and vice versa [Kappers & Bergmann Tiest, IEEE WHC 2013]. An additional result was that subjects used volume as a measure

of size and not surface area or diameter, as might have been expected from a discrimination task using different shapes [Kahrimanovic et al., 2010, Attention, Perception & Psychophysics, 72(2), 517-527]. In the current study, the adaptation stimuli were still spheres, but the test stimuli were replaced by tetrahedrons. The results are clear: the aftereffect completely disappeared. This indicates that adaptation processes are quite specific. Apparently subjects do not adapt to size (be it volume, surface area, or length) but to another object property. A suitable candidate is curvature, but more research is needed for this claim. Interestingly, subjects no longer use volume as a measure of size but either length or surface area. This confirms our earlier finding that haptic perception of volume has to be inferred from other object properties, but only if the objects are geometrically different.
[This work was supported by the EC Project THE Hand Embodied.]

◆ **Integration of shape and texture in haptic search**

30 V van Polanen, W Bergmann Tiest, A Kappers (Faculty of Human Movement Sciences, VU University Amsterdam, Netherlands; e-mail: v.van.polanen@vu.nl)

With both visual and haptic search tasks, the efficiency of the processing of object properties can be investigated. In this study, we used a 3D haptic search task in which participants had to grasp a bunch of items. We examined whether shape and texture information could be integrated. More specifically, if a target differs both in shape and texture from the distractors, performance might improve compared to targets that differ only on a single property. Experiment 1 investigated this question in three search conditions. Distractors were always rough cubes, and the target was either a rough sphere, a smooth cube or a smooth sphere. Results showed lower reaction times in the combined (smooth sphere) condition compared to both single cue conditions. This indicates that the two properties can be integrated. Experiment 2 investigated whether participants searched simultaneously for the two properties, or for the combined concept. Reaction times were not lower in a condition with two targets (a rough sphere and a smooth cube; both properties separate) compared to the search for a smooth sphere (both properties combined), even though in the latter condition the chance to find a target was lower. However, there were also some individual differences. [This work was supported by the European Commission with the Collaborative Project no. 248587, “THE Hand Embodied”.]

◆ **Implicit spatial representation of objects and hand size**

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Recent studies have investigated the body representation underlying tactile size perception and position sense. These studies have shown distorted hand representations consisting of an overestimation of hand width and an underestimation of finger length [Longo and Haggard, 2010, PNAS, 107(26), 11727-11732]. Here, we are interested in whether the observed distortions are specific to the hand or can be also detected with objects (star, box, rake, circle). Participants judged the location in external space of predefined landmarks on the hand and objects. We compared the actual and estimated horizontal and vertical distances between landmarks. Our results replicate previously reported significant underestimations of the finger length (vertical axis). There was no significant overestimation of the hand width. In the case of objects, we found a significant underestimation along the vertical axis for all objects ($p<0.01$), which was smaller than for the hand ($p<0.05$). There was no significant distortion along the horizontal axis for the star. We observed significant horizontal underestimations for the circle and the box, and a significant overestimation for the rake ($p<0.05$). In summary, distortions along the vertical axis also occur for objects. However, the size of the vertical distortion was larger for the hand than for the objects.

◆ **Moving one hand, feeling with the other: Movement information transfer**

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When we move a finger along an object with the eyes closed, we can sometimes identify its shape, size and orientation in space. However, the information available at every moment only includes the sensation corresponding to a small part of the object. To perceive the spatial properties of the entire object the brain must match the information about the finger’s movement with the successive local sensations. Usually the movement and the tactile sensation that are matched originate from the same body part - but is this a necessary condition for haptic perception? In this study, we tested the extent to which there is transfer of movement information between the left and right hands. We could have expected three different results. There could be no transfer at all. Alternatively, the brain could find a "plausible

explanation": one would feel as if the moving hand were sliding an object under the stationary, feeling hand. Finally, the brain could integrate the movement and sensory information independently of their sources. Our findings support the last hypothesis: the movement information of one hand is integrated with sensory information from the other hand into a single percept, as if they came from the same hand.

POSTERS : MULTISTABILITY, RIVALRY AND CONSCIOUSNESS

◆ **Winner-take-all circuits exhibit key hallmarks of binocular rivalry**

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Perception is inherently ambiguous. Rivalry models such ambiguity by presenting constant stimuli that evoke alternating perceptual interpretations. We modeled key phenomena that are common to nearly all forms of rivalry: i) Dominance durations, the times during which a single percept is perceived, follow a heavy-tailed distribution. ii) Changes in stimulus strength have well-defined effects on dominance durations (Levelt's propositions). iii) Long periodic stimulus removal ("blanking") stabilizes the percept, while short blanking destabilizes it. The model consisted of three coupled winner-take-all circuits with 2 excitatory and 1 inhibitory units each. We found that the network exhibited all three hallmarks of rivalry; it made novel predictions on the functional dependence of dominance durations on stimulus strength and blank duration, which we verified with 2 binocular rivalry experiments. Beyond predicting all hallmarks of rivalry, our model is well founded in neuronal circuitry. It is a generic model of competitive processes rather than tailored to explain specific aspects of rivalry. Hence our model provides a natural link from rivalry to other forms of perceptual ambiguity and to other competitive processes, such as attention and decision-making.

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◆ **Fronto-parietal cortex mediates perceptual transitions in bistable perception**

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During bistable vision, perception oscillates between two mutually exclusive percepts while the incoming sensory information remains constant. Greater blood oxygen level dependent (BOLD) responses in fronto-parietal cortex have been shown to be associated with perceptual transitions as compared to "replay" events designed to closely match bistability in both perceptual quality and timing. It has remained controversial, however, whether this enhanced activity reflects causal influences of these regions on processing at the sensory level or, alternatively, an effect of stimulus differences that result, e.g., in longer durations of perceptual transitions in bistable perception compared to replay conditions. Using a rotating Lissajous figure in a functional magnetic resonance imaging (fMRI) experiment, we controlled for potential confounds of differences in transition duration and confirmed previous findings of greater activity in frontal and parietal brain areas for transitions during bistable perception. In addition, we applied Dynamic Causal Modeling (DCM) to identify the neural model that best explains the observed BOLD signals in terms of effective connectivity. We found that enhanced activity levels for ambiguous events are most likely mediated by increased top-down connectivity from frontal to visual cortex, thus arguing for a mediating role of fronto-parietal cortex in perceptual transitions during bistable perception.

◆ **Quantitative characterization of energy landscapes in motion binding**

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Visual perception exhibits numerous cooperative phenomena suggestive of attractor dynamics, such as order-disorder transitions or hysteresis (e.g. Buckthought et al, 2008, Vision Research, 48(6), 819-830). Here we ask whether the perception of coherent motion in random-dot kinematographs (RDK) is consistent with the dynamics of a cortical network model, specifically, with an input-dependent family of 'energy landscapes' governing the evolution of state trajectories. Six observers viewed RDK in which the fraction of coherent dots followed an unpredictable random walk and reported their initial

and final percepts. The results revealed extensive path-dependence (hysteresis) of the final percept and a broad bistable regime for intermediate coherence fractions. The detailed information from random walk trials sufficed to constrain the first-order dynamical equation of a recurrently connected system (time-constant, non-linear feedback described by a general logistics function, and noise) and therefore revealed the energy landscape governing activity dynamics at each coherence level. Our analysis showed that hysteresis in the perception of coherent motion is consistent with bistability (and not with dynamical inertia) and, for the first time, quantitatively characterizes the 'basin of attraction' around a cooperative perceptual state. This opens novel perspectives for reverse-engineering the effective dynamical features of perceptual representations from non-stationary observations.

◆ **Collective dynamics of cortical columns and the distribution of dominance periods**

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We propose a novel analytical framework for the collective dynamics of cortical columns. We assume that (i) individual columns transition spontaneously between active and inactive states, (ii) stimulation increases likelihood of active states, (iii) cooperative percepts (e.g., coherent motion) integrate activity over a population of columns, and (iv) perceptual onset occurs when population activity exceeds a fixed threshold. This framework constitutes a known stochastic process, for which we obtain analytically all moments of the distribution (FPTD) of first-passage-times (times between stimulation onset and threshold crossing). Our analysis predicts mean and shape of FPTD as a function of spontaneous, stimulated, and threshold levels of activity. In low-threshold regimes, stimulated levels alter mean, but not shape, of the FPTD. This is because the mean is mainly a 'local effect' (coupling between stimulation and active times), whereas the shape is a 'collective effect' (spontaneous and threshold levels of activity). Intriguingly, the predicted dissociation is mirrored by the empirical distribution of dominance periods in multi-stable displays, where stimulation alters the distribution mean ten-fold, but leaves distribution shape almost unchanged (coefficient of variation 0.5, skewness 1.0). We conclude that the characteristic stimulus-dependence of dominance periods may reflect the collective dynamics of cortical columns.

◆ **Short-term Perceptual Stabilization in a Bistable Visual Illusion**

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During bistable perceptual illusions, perception alternates spontaneously in the face of constant input. For example, during motion-induced blindness (MIB), a salient target continues to disappear and re-appear for variable durations, when surrounded by a moving pattern. The mode of the distribution of percept durations (i.e., the most frequent MIB duration) is typically longer than 1 s and varies strongly across individuals. Why are only few percepts shorter than the mode? Here, we arbitrated between two scenarios: (i) Observers perceive rapid perceptual alternations but are too slow to report them; (ii) observers do not perceive rapid alternations, due to a mechanism that stabilizes the new percept for some time. Ten observers reported their perceptual alternations during MIB and a rapid alternation between physical target off- and onsets, which was a "replay" of MIB alternations reported by the observer with the shortest mode ("fast replay"). If the first scenario (mode of distribution limited by report) were true, observers should produce the same distributions during MIB and fast replay. In contrast, all observers were equally accurate in tracking the rapid stimulus alternations, thus producing distributions with much shorter modes than during MIB. We conclude that a stabilizing mechanism prevents short percepts during MIB.

◆ **Characteristics of bistable perception of images with monocular depth cues**

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Visual system uses a number of monocular depth cues to perceive 3D space. We have studied the characteristics of bistable perception of the images with two types of monocular depth cues (perspective and shadowing): one is a matrix of 9 Necker cubes, another one contents lines of shadowed circles ambiguously perceived either as spheres or as holes. The results show a great similarity in temporal characteristics of bistable perception of both images, which implies top-down influences upon bistable perception process. We have also analyzed neurophysiological data concerning a property of cat LGN

neurons – their sensitivity to brightness gradient orientation (Podvigin et al., 2001 Neuroscience and Behavioral Physiology 31(6), 657-668). LGN neurons were tested with the same stimulus as we used in our psychophysical experiments – a shadowed circle. The results of the analysis show the correlation between neurophysiological data and psychophysical observations. Thus the process of bistable perception of the images with monocular depth cues (such as shadowing) is likely to be based on the information from LGN neurons sensitive to brightness gradient orientation, though the final decision on what we see is apparently a result of top-down influences.

◆ 39 **Pulfrich Phenomenon and perceived number of reversals of rotation directions with stereoscopic rotary grid cube**

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Observing ambiguous stereoscopic shadow-images of an rotating Necker cube the perception changed between two different directions of rotation (reversals), while the cube itself didn't change it's direction of rotation. The stereoscopic half images originated from shadow projections, while the wire framed cube was illuminated simultaneously by a "red" and a "green" LED. Looking with one eye through a red and with the other eye through a green filter and after fusion of the two stereoscopic half images most observers perceived a rotating three dimensional cube. Sudden brightness reduction of one specific stereoscopic half image or simultaneous presentation of a brighter and a darker stereoscopic half image during the whole time of presentation caused an increase of reversals. Explanation: the fusion of the different bright retinal pictures of the rotating cube originates a Pulfrich Phenomenon causing a change form perception of the rotary cube. As a function of the direction of rotation and depending on which eye the brighter retinal picture is present, either a more flattened cube is perceived or a distorted cube with a tremendous increase in the depth. In the first case the number of reversals increased because of the reduced depth information of the flattened cube.

◆ 40 **The of role of synaptic depression and spike adaptation in perceptual memory of ambiguous visual stimulus sequences**

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Visual percept choices for sequences of repeated ambiguous stimuli depend on the time interval between subsequent stimulus presentations. Short blank intervals cause the percept to alternate, while at longer intervals the percept stabilizes into a single perceptual interpretation (perceptual memory). Here we show a biologically plausible computational model that describes the neuronal underpinnings of these choice dynamics. The model consists of excitatory and inhibitory tuned neurons and it includes, cross-inhibitory interactions, spike adaptation (with a short time constant) and synaptic depression (with a long time constant). Simulations of the model are consistent with our previous human psychophysical and monkey neurophysiological experimental data. The model predicts that adaptation and synaptic depression deterministically determine the transition from alternating to repeated percepts in sequences of ambiguous stimuli. Our model shows that no explicit (higher-order) memory or facilitatory component is necessary to explain perceptual memory effects in visual cortex.

◆ 41 **Genetic differences in dopaminergic neurotransmission link perceptual inference with delusion-proneness**

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Altered perceptual inference has been proposed as a key factor in the emergence of delusional beliefs. As dopaminergic neurotransmission has been implicated in delusion formation, we asked whether the role of beliefs in perceptual inference may be modulated by dopamine-related genes. In a behavioural study in 102 healthy volunteers we used a placebo-like manipulation to probe the effect of beliefs on the perception of an ambiguous visual motion display. Three functional haplotypes of the catechol-o-methyltransferase gene (COMT, a dopamine-degrading enzyme) were genotyped and participants completed a delusion questionnaire designed to quantify delusion-proneness in the healthy population. We found that carriers of the COMT high-activity haplotype (i.e. highest COMT-activity, lowest

synaptic dopamine availability) showed a weaker effect of experimentally induced beliefs on perception, compared to non-carriers. Moreover, delusion-proneness correlated positively with effect of beliefs on perception, and was negatively associated with the COMT high-activity haplotype. In other words, individuals carrying the COMT haplotype with low synaptic dopamine availability were both less delusion-prone and less susceptible to the effect of experimentally induced beliefs on perception. These findings provide (a) evidence for an effect of dopamine-genetics on perceptual inference and (b) a possible neurobiological substrate linking altered perceptual inference with delusion-proneness.

◆ 42 **Does punishment influence conscious visual perception? A study of binocular rivalry using operant conditioning**

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In everyday live, we perceive many things and situations and modify behavior accordingly to it. Behavior is shaped by perception. But can it also be the other way around? Can perception be shaped by our previous experiences, although we are not aware of this? Here, we addressed the question whether visual perception can be influenced by negative events. Specifically, can conditioning with monetary loss influence perceptual dominance durations in binocular rivalry? We presented blue and red grating stimuli to either of the two eyes during baseline, punishment and extinction phases. During the punishment phase, the sound of a falling coin was coupled to one of the two stimuli, representing monetary loss of 0.10 EUR every time it appeared. To avoid a reporting bias, perceptual alternations were tracked with a target detection task: Participant had to detect subtle changes of either of the two rivaling stimuli, which allowed us to infer the dominant percept indirectly. In accord with our hypothesis, we found a negative effect of punishment on dominance of the punished stimulus, while dominance increased for the other stimulus. Our results point to active adaptation of conscious visual perception to meet demands of the environment.

◆ 43 **Unconscious binding between visible and invisible stimuli reveals dissociation between attention and consciousness**

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Does binding lead to consciousness? Previous studies seem to reveal that parts of grouped objects tend to be perceived altogether, suggesting that consciousness, similar to object-based attention, emerges for the grouped object instead of accesses its parts differentially. If so, binding between visible and invisible stimuli may result in the bounded object being visible. We combined the double-rectangle cueing paradigm with the continuous flash suppression paradigm to render the corners of the two rectangles visible and the rest of them invisible when they were presented dichoptically. Same-object advantage—target shown on the cued object was judged as appearing earlier than the other concurrent target on the uncued object—was found in a temporal-order judgment task. That is, binding between visible and invisible stimuli occurred. However, the invisible part did not become visible despite the presence of object-based attention (Experiment 1). Such binding also occurred for groupings defined by semantic relations (Experiment 2). These results suggest that perceptual and semantic binding can occur unconsciously and demonstrate a dissociation of processing between consciousness and attention. While attention selects the bounded object/semantics as a whole and produces the same-object advantage, consciousness remained on the visible parts only.

◆ 44 **Simultaneous activity in V1 and IPS is critical for conscious but not unconscious visual perception**

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Conscious visual perception is known to rely on feedforward and recurrent activity along the ventral stream from V1 to temporal cortex, but the timing and contribution of parietal cortex on conscious and unconscious vision have remained poorly understood. Here, we studied the role of intraparietal sulcus (IPS) and V1 in conscious and unconscious processing by interfering with their functioning with transcranial magnetic stimulation (TMS) applied 30, 60, 90, or 120 ms after stimulus-onset. The observers (n = 13) made binary forced-choice decisions concerning the orientation (shape task) or color (color task) of the metacontrast masked target. After each trial, the participants rated their level of

conscious stimulus perception. In the shape task, TMS of V1 impaired conscious shape perception at 60, 90, and 120 ms and unconscious performance at 90 ms. TMS of IPS impaired conscious shape perception at 90 ms. TMS did not affect performance on the color task. The results suggest that simultaneous activity in V1 and IPS around 90 ms is necessary for visual awareness of shape but not for unconscious perception. The overlapping activity periods of IPS and V1 may reflect recurrent interaction between parietal cortex and V1 in conscious perception.

◆ **fMRI response patterns to invisible object stimuli predict inter-individual differences in access to awareness**

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In binocular rivalry conflicting monocular images are alternately suppressed from awareness. The temporal dynamics of interocular suppression vary considerably between individuals. Here, we asked whether inter-individual differences in suppression times for emotionally relevant object stimuli can be predicted from neural activity patterns in response to suppressed stimuli. In a behavioral experiment, we used breaking continuous flash suppression (CFS) to measure suppression times of spider and flower pictures in healthy individuals with varying degrees of spider phobia. In a subsequent functional magnetic resonance imaging (fMRI) experiment, participants then viewed the same spider and flower pictures, but this time stimuli were rendered completely invisible by CFS. We then applied support-vector-regression (SVR) to predict each participant's average suppression time, as measured in the behavioural experiment, from multivoxel pattern activity recorded in the fMRI experiment. Suppression times of spider relative to flower pictures could be decoded from fMRI multivoxel pattern activity evoked by invisible spider vs. invisible flower pictures in bilateral object-selective ventral visual cortex and in left orbitofrontal cortex. Our results suggest that inter-individual differences in unconscious processing of object stimuli determine how fast these stimuli gain access to awareness.

◆ **Looking at the smile without seeing the face - unconscious emotion processing**

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Previous evidence suggests that emotional face expressions may be processed preferentially even in the absence of awareness. However, whether facial expressions can influence observers' behavior in the objective absence of awareness has remained elusive. Here, we recorded participants' eye movements during visual search for a face rendered invisible with continuous flash suppression, an interocular suppression technique that reliably suppresses visual stimuli from awareness for extended periods of time. Faces either had a neutral, fearful, or happy expression. In a concurrently performed manual forced-choice task, participants were unable to indicate the location of the face (one sample t-test: $t(17)<1$), which objectively demonstrates that they lacked awareness of the faces. In contrast, their eye movements were more frequently directed towards the face stimulus compared to a contralateral control region ($t(17)=4.01$, $p=.001$). Most critically, there was an effect of facial expression on dwell times ($F(2,34)=11.93$, $p<.001$). Bonferroni-corrected post-hoc comparisons showed that participants dwelled significantly longer on faces with happy compared to both neutral ($t(17)=4.43$, $p=.001$) and fearful expressions ($t(17)=3.1$, $p=.02$). Our results demonstrate that even in the objective absence of awareness emotional stimuli have a considerable direct impact on oculomotor behavior, an effect possibly mediated by subcortical brain circuits.

POSTERS : TEMPORAL PERCEPTION

◆ **Saccades cause compression of time perception in the tunnel effect**

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Time length or duration is an important dimension of our perceived experiences. Here, we investigated the influence of the tunnel effect on time perception. The tunnel effect deals with the perception of a moving object that disappears behind an occluder and then reappears on the other side of the occluder. We asked participants to estimate the duration of such an event, and found that the occlusion condition (i.e., the tunnel effect) was judged shorter than a control condition with the same movement but without occlusion. We suggest that this is due to anticipatory eye movements participants made in the occluder

condition to the side of the occluder where the object was expected to reappear, which decreased perceived duration. To investigate this further, in a follow-up experiment, participants were instructed to either track the object's trajectory behind an occluder or make a saccade directly to the other side of an occluder. An eye-tracker was used to verify that the instructions were followed. The results confirmed our hypothesis that in the tunnel effect, anticipatory saccades lead to shorter perceived durations.

◆ **Temporal change in numerical magnitude modulates time perception**

48 K Sasaki[1], K Yamamoto[2], K Miura[1] ([1]Kyushu University, Japan; [2]The University of Tokyo, Japan; e-mail: k-ssk@kyudai.jp)

Previous studies have revealed that temporal change in stimulus characteristics (e.g., moving speed) modulates time perception [Matthews, 2011, Journal of Experimental Psychology: Human Perception and Performance, 37(5), 1617-1627; Sasaki et al, 2013, Perception, 42 (2), 198-207]. However, it is still unclear whether this sequence effect can also be caused by other visual features such as number. In the present study, we examined the effect of temporal change in numerical magnitude on time perception by using a temporal reproduction task. In the experiments, symbolic (digit) and non-symbolic (dot) numerosities were presented sequentially in order of increasing or decreasing magnitude. The physical duration of the stimulus sequence was 900 or 1,400 ms. The results showed that, in the 1,400-ms condition, the decreasing sequence of the digits was perceived to last longer than the increasing sequence, while this effect was not found in the 900-ms condition. On the other hand, the decreasing sequence of the dots was perceived to last longer than the increasing sequence in both 900-ms and 1,400-ms conditions. These results suggest that temporal change in numerical magnitude modulates time perception. The difference of the sequence effects between symbolic and non-symbolic numerosities is discussed.

◆ **Perceived duration of coherent and separate motions**

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Recent studies have shown that visual motion affects time perception. The duration of fast moving stimuli seems longer than slow moving stimuli (Kaneko & Murakami, 2009), and the duration of receding stimuli seems longer than approaching stimuli (Ono & Kitazawa, 2010). In this study, we examined whether motion coherence also affects time perception. We used a stimulus of McDermott et al. (2001), in which a diamond outline moves in a circular trajectory while its corners are hidden by visible or invisible occluders. Although only the movements of four line segments can be seen, observers generally perceive the single coherent motion of a diamond outline when the occluders are visible, whereas they perceive the separate motions of line segments when the occluders are invisible. With these stimuli, we compared the perceived duration between coherent and separate motions. By using a duration discrimination paradigm, we showed that the duration of the coherent motion seemed longer than the separate motions when the physical duration was 1,000 ms, not 1,600 ms. Moreover, we showed that perceived duration was not different in each duration condition when corresponding stimuli did not move. These results suggest the possibility that motion coherence also affects time perception.

◆ **Perceptual delay and the Fehrer-Raab effect in metacontrast**

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Metacontrast is a phenomenon whereby perception of a brief visual stimulus (the target) is modulated by a second brief stimulus (the mask) that surrounds and abuts it without overlap. A mask impacts perception of the target along many dimensions. Of interest to the present study is the apparent displacement in time ("perceptual delay"—Didner & Sperling, 1980) to the effect that the target is phenomenally postponed when it is masked. As opposed to this, metacontrast is also known for the Fehrer-Raab effect, such that motor responses to the target are not significantly modified by the presence of the mask. The opposition of the Fehrer-Raab effect and of the perceptual delay seems to imply two distinct routes: a motor route, time-locked to the external stimulation, and a phenomenal route that depends on a posteriori reconstruction, and integrates later events. Here, we study the interaction between these two routes, by pitting perceptual delay and the Fehrer-Raab effect one against the other within the same experimental paradigm. We show that subjective temporal estimations are improved both in terms of accuracy and precision when they are followed by a motor response to the target.

◆ **Time and time again: isochronous sequences create temporal expectations**

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Isochronous sequences can create expectations about future stimuli. Here we investigate how expectations can affect the perception of anisochronous stimuli. We presented a sequence of unimodal stimuli (either sounds or lights) with a final stimulus either isochronous or anisochronous. When participants judged whether the sequence appeared regular, anisochronies were detected more readily with longer sequences. In another experiment participants judged whether the last stimulus in the sequence appeared before or after a temporal probe in another modality. Perceived timing of anisochronous stimuli shifts towards the expected time based on the previous sequence. Overall, regular sequences affect individual stimuli so that as the number of prior stimuli increases the perceived time of the last stimulus is shifted towards isochrony while any presented anisochrony become more detectable. We modeled these seemingly irreconcilable effects using a Bayesian framework: the expectation of when a stimulus is to occur (prior distribution) is combined with sensory evidence (likelihood function) to give rise to perception (posterior distribution). If a stimulus is not presented when expected, its perceived timing is drawn towards isochrony by the effect of the prior probability and the difference between prior and posterior becomes more noticeable as the prior shapes up with longer sequences.

POSTERS : ADAPTATION AND AFTEREFFECTS

◆ **Changes in perceptual sensitivity following saccade adaptation**

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Saccade adaptation is a process which occurs when the endpoint of a saccade is systematically shifted during the saccade, leading to shortening or lengthening of saccade amplitude (Frens & van Opstal, 1994, Experimental Brain Research, 100(2), 293–306). Effects of saccade adaptation on visual perception have been noted with regard to changes in spatially-related factors such as object mislocalisation and sensory-motor system realignment (Awater, 2004, Journal of Neurophysiology, 93, 3605-3614) (Hernandez et al, 2008, Journal of Vision, 8(8):3, 1–16), or to distortion of spatial aspects within the percept, such as misperceiving the dimensions of cross figures (Garaas & Pomplun, 2011, Journal of Vision, 11(1):2, 1-11). However, effects on local image processing parameters, such as luminance or spatial frequency, have not been addressed. In this study we compare the effects of saccade adaptation on contrast-sensitivity of peripheral Gabor discrimination at multiple spatial locations. Pilot data suggest that saccade adaptation causes a steepening of the psychometric function, leading to a greater increase in Gabor discriminability at lower contrasts near the adapted endpoint, while discriminability is suppressed over all contrast levels at the original endpoint location. N = 4. These results suggest that adaptation of sensory motor space can affect contrast sensitivity.

◆ **Saccadic adaptation is not done by halves**

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Saccadic adaptation has been shown to intermediate locations in mixed shift-size trial experiments. But does saccadic adaptation also occur if only 50% of trials contain a shift? Do saccades then also adapt to an intermediate position? We recorded eye movements (Eyelink2000) in 5 subjects. After central fixation subjects had to saccade to a target. We randomly interleaved 50% shift trials in which targets were displaced by 0.7 deg during saccade with 50% no-shift trials. In a second experiment, central fixation was colored to condition shift vs. no-shift trials. In all experiments, subjects had to indicate whether they had perceived a shift or not. We analyzed average fixation locations to compare shift and no-shift trials. We found no saccadic adaptation in no-shift trials. Fixations landed on different locations in shift and no-shift trials, even though trials differed only during saccade. In color-coded experiments we found the same result, indicating that no conditioning of the saccadic adaptation process occurred using the color information. In mixed shift/noshift experiments saccades are not adapted to intermediate locations, but are in-flight corrected in each trial. The data suggest that error signals in more than 50% of trials are necessary for saccadic adaptation.

◆ **Opposite effects of adaptation and priming: Speed discriminations during smooth pursuit**

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Adaptation and priming have opposite effects. Adaptation to fast speeds lowers perceived speed; adaptation to slow speeds increases it. Conversely, priming from fast or slow pursuit causes higher or lower anticipatory smooth pursuit (ASP), respectively. Can these opposite effects occur simultaneously? Five observers performed perceptual speed discriminations while pursuing moving random dots, using the method of single stimuli. To assess the effect of adaptation on perception, we fit psychometric functions separately to responses binned according to average speed in the preceding 1-40 trials. Additionally, we analysed the residuals of binned responses from a fit to all data. Both analyses revealed perceptual adaptation: stimuli preceded by fast speeds were perceived as slower (and vice versa). To assess priming of ASP, we analysed eye velocity as a function of average stimulus speed in preceding trials, and found strong positive correlations. Interestingly, maximum ASP priming occurred for relatively short stimulus histories (2 trials), whereas perceptual adaptation was maximal for much longer histories (15 trials). Both effects could be the consequence of modifying an internal 'standard' speed representation that is used both for perceptual comparisons, and for generating anticipatory eye velocity. However, the temporal dissociation of the two effects suggests different underlying mechanisms.

◆ **Discrimination following adapation to radial motion**

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Motion adaptation is known to affect the perception of moving dot stimuli. We measured motion coherence thresholds as a function of the pedestal signal for radially-moving dot fields. The observer decided, in a spatial 2AFC task, which of two hemi-fields contained the greater amount of coherent motion. We measured the unadapted coherence thresholds for contraction and expansion, and those following adaptation to either contraction or expansion. Adaptation to radial motion clearly increased detection thresholds. Interestingly, increasing pedestal coherence did not result in a masking region, as is often observed in functions of discrimination. We discuss possible explanations and models.

◆ **Determinants of adaptation rate in the visual motion aftereffect**

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The motion aftereffect is often explained by motion sensitive neurons decreasing their firing rate with prolonged stimulation. Much less is known how the perceived motion aftereffect changes over time with prolonged exposure and how this is influenced by motion uncertainty. To answer this question, we investigate how different types of noise influence the rate of visual motion adaptation perceptually. Participants watched sequences of alternating adaptation (3 sec) and test stimuli (0.5 sec) which both consisted of randomly distributed dots. For the adaptation stimulus, dots could either all be moving in the same direction with the same speed (no noise) or moving in several different directions (noise on direction) or at several different speeds (noise on speed). Test stimuli consisted of limited-life-time dots without any specific movement direction or speed. Participants reproduced the motion perceived for test stimuli on a graphics tablet, thus indicating both aftereffect direction and strength. We found that noise within the stimulus slows down the adaptation rate. Furthermore, when switching between different levels of noise, the noise before such a switch influenced adaptation rates after the switch. These results indicate that current as well as past motion uncertainty affects the adaptation rate in the visual motion aftereffect.

◆ **Phantom motion after-effect in crowding condition: the role of awareness and attention**

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Motion after-effect (MAE) is preserved in crowding conditions. This has been shown when adapting to first- and second-order drifting gratings [Whitney and Bressler, 2007, Vision Research, 47, 569–579] as well as complex moving patterns [i.e., optic flow components; Aghdaee, 2005, Perception, 34, 155-162]. In this experiment we used global moving random dot kinematograms (RDKs) to assess whether phantom MAE [i.e., adaptation to specific sectors of the visual field induces the perception of MAE in other (non-adapted) sectors; Snowden and Milne, 1997, Current Biology, 7, 717-722] is preserved in a crowding condition, when attention was focused on the crowded target (attention-not-distracted condition) and

when attention was distracted from the target using a central RSVP task (attention-distracted condition). In the attention-not-distracted condition reliable phantom MAE was found following crowded adaptation. However, the introduction of the attentional task did not significantly affect the strength of the phantom MAE. These results suggest that high-level motion detectors can pool motion signals from different parts of the visual field in the absence of awareness and without top-down attentional control [Morgan, 2012, Vision Research, 55, 47-51].

◆ 58 **Investigating the neural regions involved in the storage of dynamic and static motion after effect using TMS**

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Prolonged exposure to directional motion biases the perceived direction of subsequently presented stimuli towards the opposite direction. This motion aftereffect (MAE) illusion is due to changes in the response of direction-selective cortical neurons. Different neural populations seem to be involved in its generation, depending on the spatiotemporal characteristics of the stimuli. The specific locus along the motion processing hierarchy where the different types of MAE take place is still debated. In particular, although MAE with stationary test stimuli (sMAE) appears to occur at early levels of motion processing, neuroimaging and neurointerference techniques have showed the involvement of various cortical sites. Conversely, while the tuning characteristics of MAE with dynamic (flickering) test stimuli (dMAE) indicate higher levels of processing, fMRI studies found a direction-selective decrease of neural activity already in V1. By using repetitive TMS (rTMS), we investigated the locus of processing of sMAE and dMAE. Results showed that rTMS over either V2/V3 and V5/MT decreased the perceived sMAE duration, indicating that sMAE is due to activity of units located at multiple sites of the motion processing stream. Conversely, no significant disruption of MAE duration was found when using a dynamic test stimulus, suggesting the involvement of higher-level processing.

◆ 59 **Where was I? Apparent onset location for moving elements is distorted following adaptation to motion**

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Past research has shown that humans make reliable errors in judging the positions of moving objects. In the Fröhlich effect, for instance, the apparent onset location of a suddenly appearing moving object seems advanced along its trajectory of motion. We have found that this effect is exaggerated for tests following adaptation to faster motion in the same direction. Neither opposite directional adaptation nor adaptation to slower movement had any impact, and the effect could not be attributed to delayed stimulus detection. These data are somewhat counter-intuitive, as adaptation to fast motion reduced apparent test speeds, and yet the positional distortion was exaggerated. These data are consistent with judgments of both perceived speed and apparent onset location reflecting weighted contributions from temporally low and band-pass mechanisms. Low-pass mechanisms are involved in signaling slow-movement (or stasis) and are characterized by protracted integration times, whereas band-pass mechanisms display the reverse contingencies. Hence the proportional contribution of low-pass mechanisms can be enhanced via adapting band-pass mechanisms through exposure to fast movement. This could result in apparently slowed movement and enhanced positional distortions, if the latter reflect the time taken to estimate the position of a moving object via positional averaging.

◆ 60 **The role of smooth purcuit eye movement on motion-induced blindness**

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Previously [New and Scholl, 2008, Psychological Science, 19(7), 653–659] showed that motion-induced blindness (MIB) could persist through slow congruent movements of the target and fixation point. We studied in detail the role of horizontal and vertical congruent movements on MIB frequency. The MIB 3D displays consisted of two targets (yellow balls) surrounded by a mask (arrays of blue balls localized in 3D space, subtending 60º by 60º and moving as a whole around a fixation central dot). Four types of 3D displays were constructed: A) the fixation point and targets were stationary; B) the fixation point and targets oscillated smoothly along the horizontal axis at 1,1 º/s; C) along the vertical axis at the same velocity. The MIB 3D displays were presented using a virtual reality CAVE system. Twenty

observers (age range 17—24) were tested. Observers reported targets disappearance by pressing joystick buttons. The results showed that MIB frequency decreased in B and C types as compared to A type. MIB disappearances for horizontal purcuit eye movement was slightly higher versus movement along the vertical axis. Our results indicate the important role of smooth-purcuit eye movement on MIB effect. Supported by the Federal Target Program (State Contract 8011)

◆ **MIB Transition for Real and After-image**

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Introduction: Time transition of Motion Induced Blindness (MIB) was investigated using the dedicated stimulus configuration. The onset and offset time delays of MIB after the inducing figures' onset and offset moments were estimated. The MIB for after image test figures was also investigated in a similar way. The after image was created in such a way that at the MIB onset moment the test figure was changed to the background color. Methods: Twelve 2.5 degree diameter colored disks were circularly arranged at 12.5 degree periphery. They were test stimuli. At the two symmetrical positions, the black ring shaped inducers were presented. They expanded from the disk border to 5.5 degree diameter in 167ms and vanished. Then the inducers shifted its position in anti-clock wise direction to the neighboring disk. The procedure repeated. Results: The short onset time delay not more than 167ms was observed. MIB effects lasted more than 333ms even after the inducers vanished. For after images, the similar onset delay was observed and MIB could last more than 900ms after the inducer vanished. Conclusions: The onset and offset time delays of MIB were confirmed in general. The delays varied quantitatively depending on the stimuli configurations and time sequences.

◆ **Evidence for mechanisms sensitive to localised orientation regularity: An adaptation study**

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A recent study by Morgan, Mareschal, Chubb & Solomon [2012, Proc Biol Sci., 279(1739), 2754-60] has provided evidence for mechanisms in the visual system sensitive to the positional regularity of elements within a grid. Similar mechanisms for the assessment of the regularity of orientation of elements have not yet been explored. Here we assess whether these mechanisms are susceptible to adaptation. Using arrays of Gabor patches via which orientation variance was manipulated and a 2AFC variance discrimination task we show that exposure to a Gabor array with a particular orientation variance does affect perceived regularity. Without the presentation of an adapter arrays with orientation variance below 0.07 radians (standard deviation of a Gaussian distribution) were indistinguishable from zero variance arrays. When observers were exposed to high variance or random adapters the perceived regularity of subsequent arrays increased ($p<0.05$, $n=6$) while zero variance adapters decreased perceived regularity ($p<0.05$, $n=6$). Additionally, no adaptation was observed when the mean orientation of the adapter was orthogonal to that of the test array. This suggests that the mechanism via which we assess variance in local orientation elements is tuned for global orientation.

◆ **Evidence for tilt normalisation may be explained by anisotropic orientation channels**

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Some data have been taken as evidence that prolonged viewing of orientations close to vertical makes them appear more vertical than they had previously – tilt normalisation. After almost a century of research the existence of tilt normalisation remains controversial. Recently it has been suggested that tilt normalisation results in a measurable "perceptual drift" toward vertical, which can be nulled by a slight physical rotation away from vertical [Muller, Schillinger, Do, & Leopold (2009), PLoS One, 4(7)]. We believe these data result from the anisotropic organisation of V1 orientation filters, which are denser and narrower around vertical than oblique orientations. We describe a neurophysiologically plausible model that predicts that, after adaptation, near-vertical stimuli should, if anything, be repelled from, rather than attracted to, vertical. Moreover, the model predicts heightened sensitivity to physical rotations toward vertical compared to rotations away from vertical, for which we present supporting psychophysical data. Given this asymmetry, we suggest that data implying a perceptual drift toward vertical could ensue from taking the average reversal value in a staircase procedure as an estimate of perceptual stasis for near-vertical stimuli.

◆ **Afterimage Filling-In Modulated By Stereo Disparity**

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Colour afterimages depend on the shape of the test image, and coloured afterimages can be perceived at regions that were not adapted (van Lier, Vergeer, & Anstis, 2009). In our study we investigated whether the afterimage filled in was modulated by the cyclopean boundaries of a 3-D stimulus. Using stereograms and shutter glasses, we presented two orthogonal bars (one in front and one occluded) as adaptation stimuli. Each bar was composed of three squares of opponent colours (green and red). The central square was grey. Adaptation was followed by a test stimulus in which the bars (both grey) could have the same, the opposite or no disparity at all. Therefore, depth stratification was varied to be the same or different from adaptation to test. Observers wore 3-D glasses and performed a colour judgment task. On each trial, they judged depth stratification and which colour they perceived the test bars to be. Most of the participants perceived the front bar (and therefore also the central square) with a colour that was filled in with the opponent colour of the bar in the adaptation stimulus. Thus, our preliminary results show that the afterimage filling-in is modulated by stereo disparity and depth stratification.

◆ **Skew hypothesis for surface gloss perception revisited by the adaptation paradigm**

65 S Nakauchi, R Nishijima, Y Tani, K Koida, M Kitazaki, T Nagai (Department of Computer Science and Engineering, Toyohashi University of Technology, Japan; e-mail: nakauchi@tut.jp)

This study performed adaptation experiments to measure the gloss aftereffect. We had subjects adapt to two images presented side by side (one of them was identical as a control) with fixating at a position between them. Following 40 s initial adaptation, two glossy surfaces were presented, and we asked subjects to judge which side of the display appeared glossier to determine the gloss aftereffects from the PSE shifts. Exp.1 used following adopters; Spec, glossy surface; Mat+, mat surface; Mat-, negative of Mat+; Rot+, mat surface with rotated specular highlights; Rot-, negative of Rot+. All the adaptors had the same value of mean luminance and RMS contrast. The histogram skew of Spec, Mat+ and Rot+ was adjusted to +0.6, and to -0.6 for Mat- and Rot-. Gloss aftereffects were obtained only for Spec, Rot+ and Rot-, and it seems that the sub-band contrasts of adaptors mainly play a role. Exp.2 investigated the skew adaptation (difference of the gloss aftereffects between positive and negative skewed adaptors) using the filtered white noise images with various cut-off frequencies. As a result, the skew adaptation was observed with clear bell-shaped frequency dependency, implying the adaptable skew processing probably at relatively early visual stages.

POSTERS : CROWDING

◆ **Attentional priming releases crowding**

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Views of natural scenes unfold over time, and objects of interest that were present a moment ago tend to remain present. Visual crowding places a fundamental limit on object recognition in cluttered scenes. Most studies of crowding suffer from the limitation that they typically involve static scenes. The role of object continuity in crowding is therefore unaddressed. We investigated intertrial effects upon crowding in visual scenes showing that crowding is considerably diminished when objects remain constant on consecutive visual search trials. Both constant target and distractor identity decrease the critical distance for crowding from flankers. More generally, our results show how object continuity through between-trial priming releases objects otherwise unidentifiable from crowding. Crowding, although a significant bottleneck on object recognition, can be strongly mitigated by statistically likely temporal continuity of objects. Crowding therefore depends not only on what is momentarily present, but also on what was previously attended.

◆ **Size of inhibitory areas in crowding effect in peripheral vision**

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We studied the influence of surroundings on the recognition of tests. The tests were Landolt rings of the diameter 1.1, 1.5 or 2.3 deg. They were centered at 13.2 deg from the fixation. The surroundings were similar Landolt rings or circles of the same size and width. The distance between the centers of the test and the surroundings varied from 2.2 to 13.2 deg. The contrast of images was 1.2 times above the threshold for each eccentricity. In one experiment, the observer had to indicate only the

location of the gap in the test. In the second experiment, the same task had to be performed, but also the observer had to detect the presence or absence of the gap in the surroundings. In both experiments, deterioration of performance was found at all separations between the test object and the surroundings, but the deterioration was more pronounced when the observer carried out the dual task. The data showed that the size of the inhibitory areas in our case does not comply with the Bouma law [Bouma, 1970, Nature, 226, 177-178]. More deterioration of performance in the dual task reveals the contribution of attention into peripheral crowding effects. Supported by RFH.

◆ **Peripheral object recognition in natural images: Effect of window size**

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Research suggests that, due to capacity limitations, the visual system pools information over sizable regions, which grow linearly with eccentricity. In many psychophysical experiments, this causes pooling over uninformative "flankers", leading to crowding. However, under natural circumstances, objects are typically surrounded by informative context. In normal viewing, how does the harmful effect of pooling over a large, potentially complex region (i.e. crowding) trade off against the beneficial effect of additional context? We conducted a recognition experiment in which we varied the size of the contextual region surrounding the object. 656 objects were randomly selected from a fully annotated picture database (SUN 2012). Objects were presented at 10 degrees from the fovea, and subtended 4 degrees visual angle. The objects appeared within a circular cropping of the original picture, with radius varying from 1 (object size) to 5 times the object size. Recognition increased monotonically from 45% to 71%, showing no detrimental effect of increasing the surround to include the typical "crowding zone". These results suggest that the visual system, faced with capacity limitations, has made a reasonable compromise. On average, for real world identification, contextual information more than makes up for the loss of information underlying crowding.

◆ **Eye-tracking shows that target flanker similarity effects both recognition and localization performance in crowding**

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A visual target is more difficult to recognize when other, similar, objects surround it. This is known as crowding. A recent model suggests that crowding is due to a combination of spatial and identity uncertainty [Van den Berg et al., 2012, J. Vision]. Crowding is most prominent in the periphery of the visual field. Since information from the visual periphery is used to plan eye-movements, this predicts that saccades would also be affected by crowding. Here, we used eye-tracking to test this hypothesis. In our experiment, targets and flankers consisting of gabor patches appeared on both sides of fixation in the peripheral visual field. One target was rotated slightly to the left, the other to the right. Participants made an eye-movement to the most leftward tilted target. Localization errors in the crowded conditions were determined relative to the targets presented in isolation. In our experiment, we find that the target-flanker similarity affected both recognition and saccadic localization performance, with the largest reductions in performance for identical target and flankers. These results indicate that saccades are affected by crowding and support the notion that crowding is due to a combination of spatial and identity uncertainty.

◆ **The role of disparity information in alleviating visual crowding**

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Crowding describes a phenomenon where visual targets are more difficult to identify when flanked by nearby distractors. We investigated the effect of flanking Gabors on the orientation discrimination of a parafoveal target Gabor. Orientation discrimination thresholds were measured as a function of flanker spacing when flankers were presented in the same plane as the target and when they were presented at a range of crossed and uncrossed disparities relative to the target. Thresholds were measured for a range of separations in the same plane. A flanker separation was chosen that induced a significant threshold elevation. Flankers were subsequently fixed at this separation for each subject while the disparity between the target and flankers was altered. Thresholds reduced systematically as the disparity of the flankers changed. The resulting tuning function was asymmetric, with flankers presented in uncrossed disparity allowing greater alleviation from crowding. Complete release from crowding was achieved when flankers were presented with sufficient disparity. In a single plane, flankers located further

away from fixation have a greater crowding effect than closer flankers. In contrast to this, we show that flankers which are closer, in terms of relative disparity, have a greater crowding effect than those which are further away.

◆ **Crowding by a single bar**

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Visual crowding does not affect much the detection of the presence of simple visual features but perturbs heavily their relative positions and combining them into recognizable objects. Still, the crowding effects have been rarely related to general pattern recognition mechanisms. In this study, pattern recognition in peripheral vision was probed using a single crowding feature. Observers had to identify the orientation (4AFC) of a rotated T presented briefly (60 ms) at a peripheral location (eccentricity 6 deg). Adjacent to the target, a single bar was presented. The bar was either horizontal or vertical, and located in a random direction (0-360 deg) from the target. It appears that such a crowding bar has very strong and regular effects on the identification of the target orientation. Certain combinations of relative position and orientation of the bar have little crowding effect while others deteriorate performance down to chance level. Different kinds of incorrect answers dominate for different combinations. It seems that responses are determined by approximate relative positions of features, exact image-based similarity to the target is not important. A simple model of pattern recognition is proposed that explains the main regularities of the data. [Supported by Estonian Ministry of Education, project SF0180027s12]

◆ **Reverse asymmetry for whole-letter confusions in crowding**

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Letter crowding is likely not a uniform process and several distinctions for its source have been proposed (letter confusion vs. letter substitution, within-character vs. between-character crowding, feature-source vs. letter-source confusion, and more). We re-analyzed our data from a three-letter contrast-threshold crowding paradigm with transient ring cue, with respect to inward-outward asymmetry of confusions of the target with a flanker. Testing was at three eccentricities (2, 4, and 6 deg) for a range of flanker distances and cue sizes in 20 subjects. The cue enhanced target contrast sensitivity but had no effect on flanker confusions. Surprisingly, confusions were asymmetric in a direction opposite to asymmetries reported for masking: The inward – not the outward – flanker was increasingly confused at increasing target eccentricities. The results support the above-mentioned distinctions of sources-to-crowding and suggest separate neural coding of pattern content and position, i.e., of what and where. The dependencies of confusions on flanker distance scale with eccentricity and are described by a generalized Bouma critical-separation rule. We propose underlying mechanisms to letter crowding where feature-binding decreases with eccentricity such that free-floating letter parts intrude from the periphery and whole letters from the center.

◆ **Lesser crowding of horizontal letter strings extends beyond parafovea**

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One recent study [Grainger et al, 2010, JEP: HPP, 36 (3), 673- 688] demonstrated that letters are less prone to crowding than other symbols. This finding, that seemingly contradicts the conventional bottom-up view of crowding [e.g. Pelli & Tillman, 2008, Nature Neuroscience, 11(10): 1129 - 1135], was further examined in our previous experiments [Vejnovic & Zdravkovic, 2012, Perception 41 ECVP Abstract Supplement, p. 160- 161]. In those experiments we found that reduced parafoveal crowding of letters was determined by string orientation: the effect was observed in horizontally but not in vertically oriented strings of three characters. Here we present an experiment in which the same 2-AFC procedure was used to test letter and symbol crowding in the peripheral visual field. Results of the peripheral experiment closely replicated those of the parafoveal experiment. Crowding of symbols did not depend on the string orientation and was comparable to the level observed in vertical strings of letters. Importantly, horizontally flanked letters received substantially lower amount of crowding. Radial-tangential anisotropy was characteristic of the crowding of both letters and symbols. [This research was supported by the Ministry of Education and Science of the Republic of Serbia (grant numbers: 179033 and III47020.]

◆ **Brain potentials reflect semantic processing of crowded words**

74 J Zhou, C-L Lee, S-L Yeh (Department of Psychology, National Taiwan University, Taiwan; e-mail: jifanzhou@gmail.com)

Visual recognition of a peripheral target is impaired when surrounded by flankers than when presented alone. This visual crowding effect, however, survives semantic processing since unrecognizable crowded words still lead to semantic priming on the subsequently presented targets [Yeh et al, 2012, Psychological Science, 23(6), 608–616]. This surprising effect raises questions how semantic meaning is obtained from crowded words. In order to get insight into the temporal dynamics of word processing in visual crowding, we examine the brain potentials during a lexical decision task for crowded words. A peripheral target was presented either alone or crowded by four flankers, and the participants were instructed to judge whether the target was a word or not. Results in the isolated condition showed a lexicality effect, with words eliciting more positive responses than nonwords in a time window ranging from 200 ms after the target onset through N400. Crowded words showed a different effect, eliciting a relatively late positive wave peaking at 550 ms. These results reflect important temporal features in processing isolated and crowded words, suggesting a critical role of a late component in distinguishing words from nonwords in a crowded condition.

◆ **Electrophysiological correlates of suppression and facilitation in crowding**

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In crowding, neighboring elements deteriorate performance on a target. The neural mechanisms of crowding are largely unknown. We have recently shown that the N1 component of the EEG is suppressed during crowding. It is difficult to disentangle the processing of the target and the flankers because they are presented synchronously. Here, we used a frequency-tagging technique to analyze EEG responses separately for the flankers and target. Subjects discriminated the offset direction of a vernier that was slowly increasing in size either to the left or right. Flanking lines were either longer than the vernier or of the same length. Flankers of the same length crowded more strongly than the longer flankers because the former grouped with the vernier. The vernier and the flankers flickered at two different frequencies. EEG responses to the vernier were suppressed and the responses to the flankers were enhanced during crowding (same length flankers) compared to uncrowding (longer flankers). Our results are consistent with the attentional hypothesis of crowding, where attention cannot be focused on the target and spreads to the flankers.

POSTERS : EMOTION

◆ **Emotional Factors in Time-to-Contact Estimation**

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Recently, the emotional content of a looming stimulus has been shown to affect time-to-contact estimation. A threatening stimulus is judged to arrive sooner compared to a neutral stimulus, possibly buying the organism time to prepare defensive actions. We investigated which aspect of the emotional stimulus content drives this effect: Is the specific valence of fear necessary for the effect, or does mere unspecific arousal speed up the reactions? We show that for healthy subjects, in a context of equally arousing stimuli, time-to-contact judgments of threatening pictures did not differ from those with positive valence. However, spider-fearful observers judged looming pictures of spiders and a frontally attacking dog, snake, or human to arrive earlier than both neutral and positively arousing pictures. Judgments of a broader range of positively and negatively arousing pictures revealed that pictures with positive valence are judged to arrive earliest (least overestimation) at a medium level of arousal. In contrast, for pictures with negative valence, a linear trend emerged: The more arousing the picture, the sooner it was judged to arrive. These results are in line with the ecologically reframed Yerkes-Dodson Law: The effect of arousal on time-to-contact judgments depends on the evolutionary relevance of the looming stimulus.

◆ **A relationship between subjective and objective measures of empathy**

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Empathy involves cognitive and affective prosocial response [Mehrabian and Epstein, 1972, Journal of Personality, 40, 525-543]. We investigated the relationship between self-reported empathy (Empathy Quotient (EQ) Questionnaire [Baron-Cohen and Wheelwright, 2004, Journal of Autism and Develop-

mental Disorders, 34, 163-185]); accuracy of recognition of emotions (20) in face and voice (Cambridge Face-Voice Battery Test [Golan et al., 2006, Journal of Autism and Developmental Disorders, 36, 169-183]) and galvanic skin response (GSR) to each affective stimulus. Participants (N=34, 17 males) were aged 23.59 ± 6.77. The EQ was found to be correlated with emotion recognition accuracy in both face (r=0.379, p=0.027) and voice (r=0.402, p=0.018) but none were correlated with the GSR. Gender differences were found in addition: compared to males, females scored significantly higher on EQ, 117.2 ± 11.2 vs. 127.4 ± 13.3 [t(32)=-2.412, p=0.022], in the visual task, 34.6 ± 5.1 vs. 40.6 ± 3.3 [t(32)=-2.699, p=0.011] and revealed greater GSR relative increment, 6.85μS ± 1.02 vs. 8.36μS ± 1.43, [t(38)=-3.837, p=0.000] respectively. Results support our hypothesis that persons reporting higher levels of empathy are better at recognising emotions, both in visual and auditory expression modes. Subjective measures of emotion recognition are, however, not related to the accompanying affective GSR.

◆ **The effect of family environment in the recognition of brief displays of emotion**

78 F Felisberti, L Cobley, E Hall, A Williams (Psychology Department, Kingston University, United Kingdom; e-mail: f.felisberti@kingston.ac.uk)

Ekman and Friesen [1971, JPSP, 17: 124-129] suggested that in certain situations we may choose to hide our feelings, but fail and show our true feelings for a fraction of a second (up to 200 ms). Such "leaked" emotional expressions are referred to as microexpressions. We investigated whether the family environment (birth order and number of siblings) could modulate the participants' ability to recognize facial microexpressions of emotion. The microexpressions (100 ms and 150 ms) tested were anger, contempt, disgust, fear, happiness and sadness. Large individual differences were observed, both in relation to accuracy and reaction time. Results showed a significant difference in the recognition of fear between participants with small (0-1) and large (=> 2) number of siblings. There was also a significant difference in the recognition of anger related to the participants' order of birth (eldest vs. youngest/ middle siblings). The results suggested that the recognition of microexpressions in adults can be affected by the complex set of interactions that occurred between siblings (or in their absence).

◆ **The stability of emotional associations of basic image attributes**

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It is widely accepted in art, marketing and other areas that single image attributes can evoke specific emotions: black colour is associated with sadness, round shapes are more positive than angular, etc. One of explanations of such effect is the link between particular image attribute and some emotionally laden stimulus, which formed during individual experience. A simple demonstration of this is the affective priming procedure – the presentation of an emotional prime has an effect on reaction to later presented neutral target stimulus. However, the use of neutral target is limited in revealing the changes of already existing associations. That is why current study uses prime and target which evoke opposite emotional reactions, in addition to only neutral target. For example, photos depicting positive content are paired with image attributes that are considered as evoking negative emotions (grey colour, triangle shape). This will allow testing the stability and strength of single image attribute associations. It is expected that neutral targets will be more prone to change compared to those which are already associated with specific emotions. Nevertheless, all targets should be subject to change depending on the prime. The implications of these results will be discussed further.

◆ **Development of method to structure image-quality evaluation model for digital camera based on human sensitivity using various words to describe feelings of being moved**

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As use of digital cameras became widespread, automatic image-processing that varies depending on the scene became familiar to everyone. However, it is unclear which image-processing settings reflect which human sensitivities. An evaluation method has not been established. The purpose of this study is to develop a method to structure a comprehensive image-quality evaluation model for digital cameras based on human sensitivity. Our focus is the feeling of being moved, one of the strongest human sensitivities, because there are many words in Japanese to express the feeling of being moved. In the first experiment, 69 words were chosen by participants according to whether the words could express the feeling of being moved in relation to image quality. In the second experiment, the relationship among words was measured by multidimensional scaling. In the third experiment, participants evaluated 180 images by

choosing among several words to describe the images. The images were plotted on two dimensions obtained by multidimensional scaling and categorised by cluster analysis. As a result, nine images were categorised as a cluster that evoked strong feelings of being moved. The images, of vast landscapes, were taken by professional photographers and used light gradation efficiently.

◆ 81 **How we evaluate what we see - the interplay between the perceptual and conceptual structure of facial expressions.**

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What do you have in mind when judging the similarity of two facial expressions? This study investigates how facial expression attributes are linked to the perceived similarity of facial expressions. Participants were shown pictures and videos of 2 types of facial expressions: 6 emotional (e.g. happy) and 6 conversational (e.g. don't understand) expressions. One group of participants was asked to rate several attributes of those expressions (e.g. "how much is the person in control of the situation", "how much does the mouth move"). Another group rated the pairwise similarity of the expressions. We explored the link between attribute ratings and perceived similarity of expressions using multiple regression analysis. The analysis revealed that different attributes best predicted the similarity ratings of pictures and videos of both facial expressions types, suggesting different evaluation strategies. To rule out the possibility that representational spaces based on expression attributes are different across pictures and videos of both expression types, principal component analysis (PCA) was applied. Significant correlations between all PCA results suggest that those representations are similar. In sum, our study suggests different evaluative strategies for pairwise similarity judgments of pictures and videos of emotional and conversational expressions, despite similar representational spaces for these stimuli.

◆ 82 **Effect of spatial frequency content of facial emotional expressions on visual search**

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Previous research has suggested threat-related visual information is processed faster than neutral or positive information. For example, saccadic latencies are shorter for orienting to fearful than neutral faces, and this effect is particularly strong for low-pass spatial frequency filtered face images [Bannerman et al., 2012, Emotion, 12(6), 1384-92]. It has also been reported that presentation of fearful faces can boost contrast sensitivity at the presentation location [Phelps et al., 2006, Psychological Science,17(4), 292-299]. In the aforementioned studies emotion was explicit - it served either as a target or a distracter. We attempted to find out if fearful faces could influence visual search performance if emotion was irrelevant to the task. In this study subjects searched for a gender oddball. We varied the spatial frequency content (low spatial frequency versus broadband) and emotional expression (fearful versus neutral). We found that removing high spatial frequency information had a larger effect on visual search time, when the array was composed of fearful faces than when it was composed of neutral ones, even though emotion was irrelevant to the task. The results suggest the fearful faces were more robust against the effect of frequency filtering, leading to faster discrimination of face gender.

◆ 83 **The relationship between expression and colour on the face perception**

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Facial colour varies depending on emotional state, and emotions are often described in relation to facial colour. In this study, we investigated whether facial expression recognition was affected by facial colour and vice versa. In the facial expression task, expression morph continua were employed: fear-anger and sadness-happiness. The morphed faces were presented in three different facial colours (bluish, neutral and reddish colour). Participants identified a facial expression between the two endpoints (e.g., fear or anger) regardless of its facial colour. In the fear-anger morphs, intermediate morph of reddish-coloured faces had more tendency to be identified as angry face, while that of bluish-coloured faces identified as fearful face. There was a similar, but a small facial colour effect on the sadness-happiness morphs. In the facial colour task, two bluish-to-reddish coloured face continua were presented in three different facial expressions (fear-neutral-anger and sadness-neutral-happy). Participants judged whether the facial colour reddish or bluish regardless of its expression. The results showed that the faces with fear and sad expression tended to be identified as more bluish. While the faces with anger and happy tended to be

identified as reddish more. These results suggest that facial expression and colour influence each other on their recognition.

◆ **Signs of disorder bias perceived facial valence in real and virtual environments**

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Virtual environments (VEs) are increasingly deployed to study the effects of environmental qualities and interventions on human behavior. Their ecological value depends critically on their ability to correctly address the user's experience. Facial expressions convey important information about emotions and social intentions of other individuals, and thereby significantly determine human social behavior. In the real world negative visual contexts (like social disorder) bias perceived facial valence [Koji and Fernandes, Can. J. Exp. Psychol., 2010, 64(2), 107-116]. We investigated if simulated social disorder also affects perceived facial valence in a VE. We measured perceived facial valence for neutral faces on photographs of an urban environment and on screen shots of a VE model of the same environment, with and without signs of social disorder. 20 participants (10 females) rated the valence of 10 neutral male faces shown on 4 different background images (real and virtual, clean and littered). Both in real and virtual imagery signs of disorder negatively bias perceived facial valence ($F(1,19)=5.9$, $p<.05$, $h2=.238$). There is no significant difference between the results for real and virtual imagery ($p=.172$). This suggests that a VE may be an ecological valid tool to study the effects of social disorder on human social behavior.

◆ **Decline in the fractal dimension of facial emotion perception due to repetitive exposure to**

85 **stimuli**

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Many studies have demonstrated that the structure of facial emotion perception can be represented in terms of dimensions of valence and arousal. Some studies have shown that this structure has a fractal dimension that differs significantly between photographic positive and negatives [Takehara et al, 2011, Perception, 40 ECVP Supplement, 74] and normal and noise-added faces [Takehara et al, 2012, Perception, 41 ECVP Supplement, 105]. In this study, we investigated the changes in the fractal dimensions of the structure of facial emotion perception in the former and latter halves of ten successive blocks. Statistical analysis revealed that the mean fractal dimension derived from the latter half (1.22 dimension) was lower than that of the former half (1.32 dimension); $t(13) = 6.18$, $p < .001$, indicating that repetitive exposure to facial stimuli might have reduced the fractal dimension. Since increase in fractal dimension is considered to be related with difficulties in perceiving facial emotions, it is plausible that the decrease in fractal dimension was due to repetitive exposure, which could improve emotion perception skill [Elfenbein, 2006, Journal of Nonverbal Behavior, 30, 21-36].

◆ **Eye candy: Looking at attractive people of the opposite gender makes men happy but not**

86 **woman**

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There is ample evidence for gender specific mating preferences: While women tend to put more importance on men's reproductive capabilities, men tend to favor female attractiveness when selecting a partner. Here we explored whether looking at attractive people induces emotions in the observer. We presented images of faces to participants (40 male and 40 females) and subsequently asked participants about their current emotional state. Specifically, we manipulated the gender (male vs. female) and the attractiveness (normal vs. attractive) of the presented faces and asked participants to report their felt happiness, sadness, and attractedness. We found that both men and women felt more attracted to attractive faces, as opposed to average faces of the opposite gender ($p<0.05$), but only men felt happier looking at attractive women and felt more sad looking at normal looking women ($p<0.001$). This result suggests a gender specific effect of attractiveness on happiness that is in line with existing theories about human mating preferences. This work was supported by the EU Grant FP7-ICT Tango 249858.

◆ 87 **Does reproduction of more precise spatiotemporal dynamics for 3D avatar faces increase the recognition accuracy of facial expressions?**

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Facial expressions are recognized by humans more accurately when they are presented in a motion picture than in a still image. A common method to create motion for facial expressions is to synthesize the intermediate image frames between the starting neutral face and the final frame corresponding to the peak of the expression by an image morphing technique (i.e., linear interpolation of the images). However, to produce more precise and solid spatiotemporal dynamics for 3D avatar faces, we adopted a different approach [Kuratate et al., 2005, Journal of the IIEEJ, 34(4), 336-343], in which a face's 3D shape model was transformed based on the motion data of a real human face measured by a motion capture system. For both the 3D shape and motion data, we calculated the displacement from the neutral face and represented them in low-dimensional parameters by PCA. By machine learning, we derived the transformation matrix applicable for estimating the parameter representing the 3D shape from that of the motion. This step allowed dynamic transformation of the 3D faces controlled by the motion capture data while generating facial expressions. Through a preliminary subjective experiment, facial expressions dynamically synthesized by our proposed method were found more perceptible than motion pictures generated by the previous linear morphing method as well as still images.

◆ 88 **Size-invariant facial expression categorization and associated gaze allocation within social interaction space**

K Guo (School of Psychology, University of Lincoln, United Kingdom; e-mail: kguo@lincoln.ac.uk)

As faces often appear under very different viewing conditions (e.g. brightness, viewing angle or distance), invariant facial information recognition is a key to our social interactions. Despite we would clearly benefit from differentiating different facial expressions (e.g. anger vs happy) at a distance, there is surprisingly little research examining how expression categorization and associated gaze allocation is affected by viewing distance in the range of typical social space. In this study we systematically varied the size of faces displaying six basic facial expressions of emotion with varying intensities to mimic viewing distance ranging from arm-length to 5 meters, and employed a self-paced expression categorization task to measure participants' categorization performance and associated gaze patterns. Irrespective of the displayed expression and its intensity, the participants showed indistinguishable categorization accuracy and reaction time across the tested face sizes. Reducing face size would decrease the number of fixations directed at the faces but increase individual fixation duration, and shift gaze distribution from scanning all key internal facial features to mainly fixating at central face region. Our results suggest a size-invariant facial expression categorization behavior within social interaction distance which could be linked to a holistic gaze strategy for extracting expressive facial cues.

◆ 89 **Holistic processing is dominant for happy expression but supplementary for surprise one: Evidence from the composite face paradigm**

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The composite face effect (CFE) has been taken as an index of holistic processing of facial identity. The CFE has also been demonstrated in the categorization tasks of facial expressions, suggesting that facial expressions should be processed holistically to some extent [Calder et al, 2000, Journal of Experimental Psychology: HPP, 26(2), 527-531]. However it is still unknown to what extent the CFE would be observed for each facial expression. In this study, we addressed this problem. In the Experiment, reaction times were measured in categorizing four facial expressions by combining positive (happy or surprise) top halves with negative (angry or sad) bottom halves and vice versa. Note that we adopted non-toothy happy and angry expressions. The results showed that when the targets were top halves, whereas strong CFE was observed for happy expression, composite faces had little effect, if any, on categorizing surprise expression. For both angry and sad expressions, moderate CFE was found. When the targets were bottom halves, the CFE was observed for all facial expressions to the same degree. These results suggest that the degree of holistic processing should be different among facial expressions: holistic processing might be dominant for happy expression but supplementary for surprise one.

◆ **Facial distinctiveness is affected by facial expressions - Examination using an intensity rating of facial expressions**

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Bruce and Young's (1986) model posited that the processes underlying facial identity and facial expression recognition are independent. However, recent studies have shown some possible interactions between those processes [e.g. Schweinberger & Soukup, 1998, Journal of Experimental Psychology, 24(6), 1748-1765; Fox et al, 2008, Journal of Vision, 8(3), 1-13]. Relating to this issue, Takahashi and Yamada (2012) examined whether facial distinctiveness was affected by facial expressions, and reported that happy face could keep or maintain the distinctive properties of neutral face but sad face couldn't. We examined the relationship using intensity of facial expressions. We used 168 images of twenty four persons' face with neutral and six facial expressions (happiness, surprise, fear, sadness, anger and disgust) as stimuli and asked participants to rate intensity of those facial expressions. Comparing correlation coefficients between distinctiveness ratings based on Takahashi and Yamada (2012) and intensity of them indicated that the modest correlation coefficients were shown between intensity of surprise and distinctiveness in surprise, fear and anger images, between intensity of fear and distinctiveness in surprise and sadness images, and between intensity of anger and distinctiveness in disgust images. Those results suggest the relationship between physical components of surprise, fear and anger in each facial image and facial distinctiveness.

◆ **Recognition of emotions for composite expression faces**

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By using composite expression faces, namely, smiling faces with neutral eyes or mouth, and neutral faces with smiling eyes or mouth, the interactions between facial parts were examined for recognition of facial expressions of emotion. For these composite expression faces and original faces, three conditions (whole faces, lower halves of faces and upper halves of faces) were prepared. Twenty-five Japanese undergraduates were asked to rate all presented faces for seven emotions: happiness, sadness, anger, disgust, fear, surprise and interest, and rank them on a scale of one to six. Two-way ANOVA showed that the main effects of stimulus conditions and expressions and the interactions were all significant to 1%. Multiple comparisons were made for happiness ratings. Results showed we perceive happiness most strongly from whole smiling faces. We can recognize happiness from the upper halves of faces with smiling eyes, or whole smiling faces with neutral mouth. The eyes are sufficient for recognizing happiness, but results showed that smiling eyes in whole, neutral faces appeared disgusted and did not increase recognition of happiness. Interaction is not additive between smiling eyes and neutral whole faces.

◆ **Noise masking analysis of facial expression perception**

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We used a noise masking paradigm to investigate the facial expression detection mechanisms. The targets were pictures of faces with happy, sad, fearful, angry or neutral expression. The masks were random dot patterns. A 2AFC paradigm was used to measure target contrast threshold at 75% accuracy. In each trial, the noise was presented in both intervals and the target was in one interval. In the face detection (FD) conditions the non-target interval contained the phase-scrambled version of the target while in the expression detection (ED) conditions it contained a face of neutral expression. The observer was to indicate the target interval. In all conditions, the target threshold vs. masker contrast (TvC) functions were flat at low masker contrast and increased with masker contrast when the masker contrast was beyond a critical value. The thresholds for happy faces in both ED and FD conditions were the same at all noise level, suggesting happy might be the default expression. For other expressions, the ED contrast thresholds were more than 50% greater than the corresponding FD thresholds and the ED critical values were greater than the FD ones. The results suggest that the ED mechanisms are less sensitive to contrast than FD ones.

◆ **Sequential effects in attractiveness judgment for upright and inverted faces**

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One-by-one decision making for sequentially presented stimulus is biased by the stimulus and response in the preceding decision (the sequential effect). Kondo et al. (2012) have shown that attractiveness

judgments for faces are also biased toward those in the preceding trials. In the present study, we further investigated the sequential effects in face-attractiveness judgment, in terms of the influence of gender membership and face orientation. Forty-eight pictures of male and female faces were presented in a random sequence. Participants rated attractiveness of each face on a 7-point scale. All face stimuli were upright in one session, while the faces were inverted in the other session. The results showed the robust sequential effects irrespective of the orientation of the faces. Furthermore, in the upright face session, we found the weaker sequential effects when the gender of the face being rated and that in the preceding trial were same (between-gender dependency) than when they were different (within-gender dependency). In contrast, the between-gender and within-gender dependency were comparable in the inverted face session. These findings suggest that the sequential judgment for face-attractiveness is influenced by the gender membership of faces only when the faces are viewed in the upright orientation.

◆ **Cross-modal adaptation on facial expression perception**

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While visual adaptation is well explored, relatively few studies have examined cross-modal adaptation (Fox & Barton, 2007). Here, we investigate whether adaptation to an auditory signal can bias the perception of facial expression. We adapted participants to spoken sentences with a "happy" content and voice, and we measured judgments of facial emotion (auditory->visual). We found no significant aftereffect. In a second experiment, we adapted subjects to the "happy" spoken sentences together with a happy/sad face, and tested on facial expression judgment (auditory + visual -> visual). We also measured simple visual adaptation (visual->visual). Again, we found no increment/decrement aftereffect as a result of exposure to the additional auditory signal. However, we found that reaction time can be reduced by the auditory signal. This reduction depends on the co-presented visual signal. In happy-face adaptation, the reduction is significant when the test faces are happy; in sad-face adaptation, the reduction in reaction time occurs when the test faces are sad: a priming effect. These findings suggest that instead of a cross-modal aftereffect by adaptation to an auditory signal, sound plays a role as a prime, and the effect of priming depends on the state (happy/sad) of the other mode (visual) during adaptation.

◆ **Specific EEG/ERP responses to animated facial expressions in virtual reality environments**

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Visual event-related potentials of facial expressions (FEs) have been studied using usually static stimuli after a nonspecific black screen as a baseline. However, when studying social events, the ecology of the environment and stimuli can be a bias. Virtual reality provides a possible approach to improve ecology while keeping stimulus control . We propose a new approach to study responses to FEs. A human avatar in a virtual environment (a plaza) performs the six universal FEs along the time. The setup consisted of a 3D projection system coupled with a precision-position tracker. Subjects (N=7, mean age=25.6y) beared a 32-channel EEG/ERP cap together with 3D glasses and two infrared emitters for position tracking. The environment adapted in real time to subjects' position, giving the feeling of immersion. Each animation was composed by the instantaneous morphing of the FE, which is maintained for one second before the 'unmorphing' to the neutral expression. ISI was set to three seconds. For the occipito-temporal region, we found a asymmetrical negativity [200-300]ms after stimulus onset, followed by a positivity on the centro-parietal region at latency [450-600]ms. Given the neutral face baseline, these observations suggest the identification of two specific neural processors of facial expressions.

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◆ **Synthetic Face Adaptation Reveals Neural Tuning**

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Introduction: Prolonged viewing of a face can influence the appearance of subsequently-viewed faces. We aimed to quantify the magnitude of face adaptation for unfamiliar synthetic faces as a function of face identity and face distinctiveness. Methods: Observers adapted to synthetic faces with specific identity and distinctiveness. Face discrimination sensitivity against a mean face was assessed for the adapted identity (congruent condition) and novel identities (incongruent). Baseline sensitivity was measured with

a low-level noise adaptor. Results: Face discrimination sensitivity was unchanged by adaptation to the mean face. Equally, incongruent conditions did not differ from baseline. Congruent face discrimination thresholds, however, were significantly elevated. The magnitude of this elevation was related to the distinctiveness of the adapting face, ranging monotonically from 1.37 (least distinctive adaptor) to 2.38 (most distinctive). Conclusions: Synthetic face adaptation resulted in an identity-specific reduction in sensitivity. Adaptation did not transfer between identities. The magnitude of the adaptation in the congruent-identity condition showed a monotonic dependence on face distinctiveness: the more distinct the adaptor, the stronger the adapting effect. This suggests a norm-based representation of faces with neural populations tuned to face identity and distinctiveness that respond with increasing magnitude as faces become more different from the mean.

◆ **Perception of traits from static and dynamic visual cues in faces and bodies**

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Although body and facial features affect social judgements about others [Allison et al, 2000, Trends in Cognitive Sciences, 4(7), 267-278], it is unclear how static and dynamic visual features are related to the perceived traits of others. Using images of both familiar and unfamiliar characters, we examined how visual information from faces and body motion is related to trait perception. In Experiment 1, we recorded videos of 26 unfamiliar actors portraying their interpretation of either a 'hero' or a 'villain'. Participants rated these body motions according to an 'Effort-Shape' analysis [Thoresen et al. 2012, Cognition, 124, 261-271]. We found consistent differences in the type of body motion associated with 'heroes' versus 'villains'. In Experiment 2, we selected neutral expressive face images of 140 hero and villains from the media (100 well-known, 40 lesser-known). Participants categorized each image as hero or villain based on a 2-AFC design. Trait accuracy was unrelated to character recognition and was higher for lesser-known 'villain' compared to 'hero' faces. The findings suggest that specific visual features from body motion or the face are important for the perception of high-level social information such as traits [Todorov et al., 2013, Current Opinion in Neurobiology, 23, 1-8].

◆ **Quantifying Human Sensitivity to Spatio-Temporal Information in Dynamic Faces**

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A great deal of social information is conveyed by facial motion. However, understanding how observers use the natural timing and intensity information conveyed by facial motion is difficult because of the complexity of these motion cues. Here, we systematically manipulated animations of facial expressions to investigate observers' sensitivity to changes in facial motion. We filmed and motion-captured four facial expressions and decomposed each expression into time courses of semantically meaningful local facial actions (e.g., eyebrow raise). These time courses were used to animate a 3D head model with either the original time courses or approximations of them. We then tested observers' perceptual sensitivity to these changes using matching-to-sample tasks. When viewing two animations (original vs. approximation), observers chose original animations as most similar to the video of the expression. In a second experiment, we used several measures of stimulus similarity to explain observers' choice of which approximation was most similar to the original animation when viewing two different approximations. We found that high-level cues about spatio-temporal characteristics of facial motion (e.g., onset and peak of eyebrow raise) best explained observers' choices. Our results demonstrate the usefulness of our method; and importantly, they reveal observers' sensitivity to natural facial dynamics.

◆ **Mere exposure effect for amodally completed faces**

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The mere exposure effect (MEE) refers to the phenomenon where repeated exposure to a stimulus results in an increased liking for that stimulus. When a shape is partially occluded, observers usually perceive the contours to be continuous (i.e. amodally completed) behind the occluders. This study investigates whether the MEE would generalize to amodally completed perceptual representations. We used line drawings of faces as stimuli, which were overlaid with square-wave grating occluders

(i.e. stripes). During the exposure phase, 50%-occluded faces were repeatedly presented to observers. During the rating phase, the observers rated the likability of the same 50%-occluded faces, non-occluded faces, and faces occluded by gratings which were half-cycle shifted. The result indicated a significant MEE for the same 50%-occluded faces and the non-occluded faces. Therefore, the MEE generalizes to amodally completed perceptual representations. However, when the faces were inverted, the MEE did not generalize to non-occluded faces. These results indicate that face-specific processing helps the MEE to generalize to amodally completed representations. Moreover, no observer was aware that the grating occluders were half-cycle shifed in some stimuli. The present study suggests that even when observers cannot consciously distinguish similar stimuli, the visual system can at the level of affective preference.

◆ **Do I have my attention? Our own face may be special, but it does not grab our attention more than other faces**

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We respond more quickly to our own name and face than to other names or faces, but there is debate over whether this is connected to attention-grabbing properties of self-referential stimuli. Two experiments investigated whether different types of face (self, friend, stranger) provide differential levels of distraction when processing self, friend and stranger names. In Experiment 1, an image of a face appeared centrally (upright or inverted) behind a target name. In Experiment 2, distractor faces appeared peripherally in the LVF, RVF or bilaterally. For both experiments, self-faces did not increase distraction (RT) relative to other faces, and RT was always fastest for self-name recognition. Distractor faces had different effects across the two experiments: when presented centrally, self and friend images facilitated self and friend naming, respectively. This was not true for stranger stimuli, suggesting that faces must be robustly represented to facilitate name recognition. When presented peripherally, no facilitation occurred, but images of friend faces negatively affected RT for recognising strangers' names. In conclusion, our own face does not grab more attention than other faces, faces must be central to attention to facilitate name recognition, and the distracting effect of a friend's face is only evident when presented peripherally.

◆ **Gains and costs of visual expertise – a training study with novel objects**

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Adult observers typically have remarkable face recognition skills and are therefore considered face "experts". The mechanisms mediating these skills and especially their relation to other domains of visual expertise are still debated. In the present study, we investigated whether behavioral markers of face expertise could be obtained with novel non-face objects after lab-based training. Observers' performance with both faces and novel 3D objects was assessed before and after training using matching tasks previously shown to elicit face composite, face inversion, and face contrast reversal effects. During several hours of training, observers learned to individuate novel objects from different viewpoints using a number of naming and verification tasks. As predicted, pre-training results revealed the composite, inversion and contrast reversal effects in efficiency for faces but not for non-face objects. Preliminary post-training results showed that the magnitude of the effects for faces diminished relative to pre-training results whereas the effects for objects increased. This overall pattern of results is consistent with competition for neural resources between face and non-face domains of expertise and highlights the plasticity of visual processing mechanisms even at an adult age.

◆ **The Mooney Face Task: Genetic, phenotypic, and behavioural associations**

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The Mooney Face Task is a test of face detection, which is often used and is quoted as a measure of holistic processing. We tested 370 healthy adults (235 female) of European descent, between the ages of 18 and 42 (M = 24 years) on our custom-made three-alternative forced-choice version of the Mooney Face Task. In a genome-wide association study we identified a single-nucleotide polymorphism (rs1522280, located within the gene RAPGEF5), to be associated with performance on the Mooney Face Task ($p = 5.1 \times 10\text{-}9$): participants who are homozygous for the major allele score on average .37 standard deviation higher than participants who are heterozygous, who in turn score on average .62 standard deviation higher than participants who are homozygous for the minor allele. Furthermore,

we observed significant sex differences modestly favouring males (.31 standard deviation increase in performance; p = .004), and a significant positive correlation with digit ratio regardless of sex: a higher digit ratio is associated with higher performance (r = .14, p = .028). This is the first genetic association with performance on a test of face perception. It opens the door to a new approach for understanding the perception of faces.

◆ 103 **Assessment of individual psychological characteristics based on perception of photographic image of human face with the use of SensoMotoric Instruments**

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The purpose of this research is to study perception of normal and morphed faces. The aspects explored are psychological characteristics which were attributed to each face by subjects of the experiment. These characteristics include activity, tenseness and sociability. To achieve thorough understanding of the main factors which influence perception of human face we registered ocular motor activity of all the subjects during the experiment. Each picture was exhibited during two seconds. After the first part of the research was conducted we discovered independence of personality appraisal from the fixation patterns under current experimental conditions. Visual survey paths were proved to be generally uninfluenced by facial structure while connection between assessment of personal characteristics and facial feature structure was revealed. The former may be accounted for either by the fact that triangle "left eye-right eye-nose (mouth)" contains traits on which assessment is based or by the "peripheral vision" effect. Thus, the role of this effect in the process of facial perception may be significant and is to be discussed in the current research.

◆ 104 **'Face inversion effect' on perception of the vertical gaze direction**

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'Face inversion effect' refers to impaired recognition of faces when rotated away from the upright position. This study examined 'gaze inversion effect', which is introduced as impairment in perception of a gaze direction in inverted faces as compared to upright faces. In the first experiment we manipulated the vertical eye and head orientation in upright and inverted digital images of the real and CG faces. An error in reported gaze locations was particularly large in inverted faces and at large eye-to-head rotation angles. It occurred in the opposite direction to both the eye rotation and the head rotation. The second experiment measured a tolerance range of a mutual gaze in upright and inverted faces. The range of gaze directions within which observers report that the gaze of another person is directed at them characterizes a mutual gaze. Observers were asked to adjust the eyes of the CG generated face to the margins of the mutual gaze area (Gamer and Hecht, 2007, Journal of Experimental Psychology: Human Perception and Performance, 33, 705-715). Results showed that the face inversion does not alter direction of the gaze per se, but the tolerance range was substantially larger in inverted faces.

◆ 105 **Does the visual perception strategy differ during impression judgments of faces in different individual attributes?**

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People attribute personality traits to strangers on the basis of facial appearance. The underlying strategy in the visual perception of impression judgment, however, remains an open question. We investigated whether different face features are gazed at while making impression judgments of individual attributes. We sequentially presented on a monitor arbitrary pairs of ten synthesized face images, each of which was generated by averaging the face images of the same age and gender group. Subjects decided which one was more extreme with respect to the personality trait in question, while their eye-movements were measured by a rapid eye-movement measurement system. The eye-movement results were represented in 2D histograms that indicated the spatial distribution of the cumulative duration of the gaze at each fixation point, and the positions corresponding to the mode of each histogram were analyzed by ANOVA. The results of our preliminary experiments suggest that the attention to facial features inferred by the eye movement measurement is affected by the diversity of the impression judgments, i.e., seniority and sociability [Nakamura et al., 2012, Perception, 41 ECVP Supplement, 165]. In this experiment, we

investigated how eye movement is influenced by the content of the personality traits during impression judgments.

◆ **„He's got his father's nose! " – Factors involved in kinship – perception**

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In the field of face research, only few studies took a close look on kinship-perception. Previous research has shown, that we are able to identify related pairs of faces better than chance, but a lot about the processes and factors involved in detecting kinship is still unknown. We were particularly interested in whether kinship-similarity is influenced by more featural or more holistic aspects of faces. Our participants inspected pairs of unrelated faces which were (a) manipulated so that one single feature (eyes, nose or mouth) was identical in both faces, (b) morphed into one another so that one face was similar to the other in all features and proportions to a certain degree, or (c), as a control condition, not changed at all. When rating the kinship-probability for each pair, holistic as well as featural aspects had a positive effect on the kinship-similarity, but holistic aspects were clearly of stronger relevance than single features. For featural manipulations, identical eyes were the strongest predictor of perceived kinship, followed by the mouth and the nose. Those results are conform to other studies on similarity, recognition as well as on processing onsets of face perception.

◆ **The preview benefit for familiar and unfamiliar faces**

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Previewing distracters improves visual search, termed the preview benefit. Recent fMRI evidence suggests that the preview benefit rests on active inhibition in brain regions concerned with spatial memory, and in content selective areas (Allen, Humphreys, & Matthews, 2008). Using familiar and unfamiliar faces in a preview search task it is shown that search performance is much better with familiar than with unfamiliar faces. With both types of stimuli we obtained preview benefits of at least 10%, measured in terms of the advantage in reaction time relative to the no preview condition. The preview benefit increased up to 30% when distracter faces and their locations were previewed, compared to a benefit in the range of 10% to 25% for previewing just distracter locations. Analysis in terms of search time per item showed that familiar faces were processed with more than double the efficiency of the unfamiliar faces. Further, efficiency was enhanced relative to the no preview condition only when distracter locations and content were previewed, but not when subjects previewed just distracter locations. These findings corroborate that the preview benefit involves both spatial and content-specific mechanisms, and indicate contribution of existing long-term memory representations independent of spatial memory.

◆ **Inaccuracies in judging aspect ratio of familiar and unfamiliar faces**

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Researchers have suggested configural information is critical in face identity processing (Maurer et al., Trends Cogn Sci 6: 255-60, 2002). However, observers are very inaccurate at estimating the distances between the features of unfamiliar faces (Schwaninger et al., Vision Res 43: 1501-15, 2003). In this study, we ask whether viewers show evidence of having good representations of the spatial relationship between features of familiar faces. Configural face processing theories seem to imply that such representations will be highly accurate, given that differences in spatial layout between faces are rather subtle. In several experiments, we asked viewers to correct faces seen in the wrong aspect ratio, using a mouse to re-size a window. Participants were poor at this task, making 8-9% errors for both familiar and unfamiliar faces – this performance being worse than an equivalent task using geometric shapes. Knowledge of a face did not help participants accurately to render the spatial layout of features in this simple aspect-ratio task. These findings challenge theories of face identification based on the spatial layout of features. For such theories to be useful, it will be necessary to explain exactly how to operationalize face configuration, and for such an operationalization to be robust in the face of quite severe distortions in aspect ratio.

◆ **Extracting mean and individual identity from sets of famous faces**

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We can accurately extract a variety of information from a single face, such as a person's gender, emotional state, or identity. When seeing crowds – or sets – of unfamiliar faces, participants rapidly code a mean identity representation of the set. Here, we examine ensemble coding for familiar faces, for which participants have rich pre-existing mental representations. In the first experiment, participants saw sets of faces, each consisting of four different celebrities of the same sex. Following each set, a single probe face appeared and participants indicated whether or not it had been presented in the previous set. As expected, participants very accurately identified the actual set celebrities. Strikingly, they also consistently gave large proportions of "present" responses when the probe was a morphed face created from the previous set's celebrities (the "set mean"). This is the first data suggesting that ensemble coding of identity occurs for famous faces. In a second experiment, ensemble coding for facial identity was reduced when sets consisted of each two male and two female faces. In conclusion, mean set identity appears to be extracted from famous face crowds in parallel with accurate exemplar representations, when set exemplars belong to a common subcategory (e.g., same gender).

◆ **ERP face sensitivity onset in a sample of 115 subjects = 92 ms [86, 98]**

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When does the human visual system detect faces? Several scalp and intracranial recording studies have suggested that activity 100 ms post-stimulus differentiates between faces and other object categories. However, these results could be compromised by three problems: high-pass filtering at 1 Hz and above, which can smear the onsets back in time (Rousselet, 2012, Frontiers in Psychology, 3:131); lack of control for multiple comparisons; group statistics, which ignore individual differences. Here, we addressed these problems by measuring onsets in every subject after applying a causal Butterworth high-pass filter, which does not distort onsets, and a spatial-temporal percentile-t bootstrap correction for multiple comparisons. A large sample of subjects (n=115), spanning a wide age spectrum (18-81 years old), viewed images of faces and phase-scrambled noise textures. The first significant ERP differences between faces and textures had a median of 92 ms and 95% confidence interval = [86, 98]. These onsets were reliable (test-retest in 80 subjects), without significant group differences between sessions: difference = 2 ms [-11, 14]. These onsets did not change with age, were not affected by low-pass filtering, and were not over-estimated due to possible outliers, as demonstrated by similar results obtained by testing trimmed means instead of means.

◆ **Not only the face matters: Influence of random noise backgrounds with different statistical**

111 **properties on face attractiveness**

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The human visual system is adapted to processing the scale-invariant higher-order statistics of complex natural scenes efficiently. Previous studies found that man-made aesthetic images, such as visual art, art portraits and cartoons, share scale-invariant properties with natural scenes. Here, we investigated the influence of different random noise backgrounds on the subjective evaluation of face attractiveness. To this aim, we presented face images in front of backgrounds with five different slopes of the log-log Fourier power spectrum (slope 0, -1, -2, -3 and -4), in which high or low spatial frequencies were enhanced or attenuated, respectively. A slope of -2 indicates scale invariance. We found a significant quadratic influence of the background slope on the attractiveness ratings. Participants rated the same faces in front of an approximately scale-invariant background as more attractive than on the other backgrounds. This result shows that perceived attractiveness of faces can be modulated by higher-order image statistics that may be processed at early stages of visual perception. This modulation was observed even if the image of the face itself was not modified and, consequently, evolutionary adapted indicators of attractiveness, such as symmetry, averageness and secondary sexual characteristics, remained constant.

◆ **No spatial frequency hemispheric specialization in face recognition at final stages of visual processing**

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Spatial frequency (SF) hemispheric specialization for recognizing faces was investigated psychophysically at the final stages of visual processing. Men and women were asked to rate their recognition confidence to new and old face pictures, previously submitted to low-pass and high-pass SF bands filters, after 300 ms exposures in the left and the right visual field. It was used one adaptation of the divided visual field technique. The corrected recognition taxes and the Az parameters (area under zROC curve) indicated no significant hemispheric specialization for low and high SF in the overall sample. Taking into account literature, this absence of SF hemispheric specialization may be explained: (a) by that the sensitivity to different SF bands is retinotopically mapped in the visual cortex; (b) by that the lateralized presentation reduces asymmetry effects; and (c) by that the SF hemispheric specialization only is noticed at early stages of the processing visual.

◆ **It's a girl! Opponent versus multichannel neural coding of face gender**

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Although we can easily categorise the gender of a face, the underlying neural mechanisms are not well understood. Recently, Zhao et al. (2011) measured the size of aftereffects induced by adaptors with increasing levels of gender-caricaturing, to determine whether gender is opponent or multichannel coded. The opponent coding model predicts aftereffects to increase as adaptor extremity increases. The multichannel coding model also predicts increased aftereffects for small increases in adaptor extremity. But, as adaptors become very extreme aftereffects should decrease. Zhao et al. (2011) found reduced gender aftereffects for the most extreme adaptor levels, which they interpreted as evidence for multichannel-coding of gender. However, this interpretation assumes that the perceived gender of faces increases with increasing exaggeration of differences between male and female faces. Here we show that this is not the case over the very large range of gender-caricaturing that they used. We also show that gender aftereffects increase monotonically with increasing levels of gender-dimorphism over twice the normal range. Moreover, we found an almost perfect correlation between the perceived level of gender dimorphism of the adaptor and the magnitude of gender aftereffects. These findings support opponent coding of facial gender.

◆ **Subjective facial attractiveness is correlated with low-level properties of images**

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Several properties of faces have been proposed to contribute to subjective ratings of attractiveness. In particular, high-level properties such as symmetry, secondary sexual characteristics and several ratios and distances (e.g., between eyes and mouth) affect attractiveness ratings. The aim of the present study was to investigate whether other (low-level) properties of face images also correlate with attractiveness ratings. We analyzed low-level statistical properties of face images that were rated for attractiveness and found that attractiveness correlated negatively with self-similarity (measured by Fourier transform and PHOG analysis) and positively with complexity and anisotropy. Furthermore, we found positive correlations of self-similarity with the age of the depicted person. In a follow-up experiment, we changed the slope ratio in log-log plot of radially averaged Fourier power (an established measurement for self-similarity) of face images. Participants rated a version of the same face, which was rendered less self-similar, as significantly less attractive. This result can be explained if one assumes that high correlations of self-similarity with age mask the negative correlation with attractiveness. In conclusion, we demonstrated a relation between low-level image properties, such as self-similarity, complexity and anisotropy, on judgments on attractiveness as well as on the age of faces.

◆ **Is the mere exposure effect in face attractiveness image-based or face-based?**

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According to the Mere Exposure Effect (Zajonc, R.B. 1968 Attitudinal effects of mere exposures. Journal of Personality and Social Psychology, 9, 1-27) repeated exposures of a face increases the preference for that face (e.g. Peskin M, Newell F.N, 2004, Familiarity breeds attraction: effects of exposure on the attractiveness of typical and distinctive faces. Perception, 33, 147–157). The effect is typically obtained with a single, repeated image of a person, randomly presented with other face images. Yet, faces are often seen across different images. Here we investigated whether the MEE is affected by image changes such as facial expression or viewpoint. We found no difference in attractiveness ratings to repeated, random exposures of face images shown in a neutral, happy or angry expression (Experiment 1). However, when face images were presented continuously for each person, we found higher ratings for 'happy' expressions (Experiment 2). Furthermore, ratings were higher for continuous image exposures than exposures to different images of the same person across viewpoints (Experiment 2). Ratings also increased the more frequently a person's face image was presented as 'happy'. These findings suggest that the MEE is image-based, rather than person-based, and suggest its generalizability to the real world is limited.

◆ **Craniofacial Abnormalities Divert Attention Away From the Core Features of the Face**

116 **During Aesthetic Judgments**

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The level of cuteness in an infant face influences the elicitation of care-giving behaviour from adults. When making aesthetic judgments about faces, attention is primarily focused on the eyes and nose (Kwart et al, 2012, Perception, 41, 925-938). For infant faces, any factor that diverts attention away from these features may disrupt the perception of cuteness and, in turn, reduce the elicitation of care-giving behaviours from adults. The present study examines the extent to which common craniofacial abnormalities of infancy divert attention away from these core features. Participants were presented with faces that either had no abnormality, a cleft-lip, a haemangioma, or strabismus. The participants judged either how cute, or how attractive they thought each face was on a 7-point scale while their eye movements were tracked. The results showed a significant effect of abnormality type on dwell times for the AOI's. For images with abnormalities outside the core features there was a significant reduction in the dwell time on the eyes and an increase in the dwell time on the area with the abnormality. Overall, the results demonstrate that craniofacial abnormalities divert attention away from the core features during aesthetic judgments.

◆ **Impact of make-up on facial contrast and perceived age**

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Facial contrast influences our perception of femininity and age. Make-up exaggerates facial contrast making a face to appear more feminine. It has also been shown that facial contrast decreases with age, and digital manipulations of facial contrast changed the apparent age of the face. Does make-up impact on age perception? Our purpose was to study the influence of make-up on age perception, for faces from different age groups. We also studied the link between perceived age and the modifications of facial contrast due to make-up. Thirty two Caucasian women, aged from 18 to 52 years, were made up by a professional and pictures taken during 6 steps. Caucasian female participants (N=132) were then asked to estimate the age of the faces without make-up and at each step of make-up. Moreover, luminance and color facial contrast (eyes, lips and brows) were measured on each photograph. Results showed that make-up modified perceived age, increasing the apparent age of the youngest women and decreasing the apparent age of the oldest women. For older women, high contrast make-up reduced perceived age, but low contrast make-up increased perceived age; whereas for younger women, make-up increased perceived age whatever the contrast modification.

◆ **Looking at faces from different angles: Europeans fixate different features in Asian and**
118 **Caucasian faces**

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The other-race effect is the widely known difficulty at recognizing faces of another race. Further, it has been clearly established in eye tracking studies that observers of different cultural background exhibit different viewing strategies. Whether those viewing strategies depend also on the type of faces shown (same-race vs. other-race faces) is under much debate. Using eye tracking, we investigated whether European observers look at different facial features when viewing Asian and Caucasian faces in a face race categorization task. Additionally, to investigate the influence of viewpoints on gaze patterns, we presented faces in frontal, half profile and profile views. Even though fixation patterns generally changed across views, fixations to the eyes were more frequent for Caucasian faces and fixations to the nose were more frequent for Asian faces, independent of face orientation. In contrast, how fixations to cheeks, mouth and outline regions changed according to the face's race was also dependent on face orientations. In sum, our results indicate that we mainly look at prominent facial features, albeit which features are fixated most often critically depends on face race and orientation.

◆ **Learning Faces from Multiple Viewpoints Eliminates the Other-Race Effect**
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People recognize own-race faces more accurate than those of other races. This other-race effect (ORE) has been frequently observed when faces are learned from static, single view images. However, the single-view face learning may prevent the acquisition of useful information (e.g., 3D face shape) for recognizing unfamiliar, other-race faces. Here we tested whether learning faces from multiple viewpoints reduces the ORE. In Experiment 1 participants learned faces from a single viewpoint (left or right 15° view) and were tested with front view(0° view) using an old/new recognition task. They showed better recognition performances for own-race faces than that for other-race faces, demonstrating the ORE in face recognition across viewpoints. In Experiment 2 participants learned each face from four viewpoints (in order, left 45°, left 15°, right 15°, and right 45° views) and were tested in the same way as in Experiment 1. Participants recognized own- and other-race faces equally well, eliminating the ORE. These results suggest that learning faces from multiple viewpoints improves the recognition of other-race faces more than that for own-race faces, and that previously observed ORE is caused in part by the non-optimal encoding condition for other-race faces.

◆ **Own-race and own-university biases in eye movements for face processing**
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The well documented own-race bias in face recognition (Goldinger, He & Papesh, 2009, Journal of Experimental Psychology: Learning, Memory and Cognition, 35(5), 1105-1122) is explained either by perception (viewers' lower perceptual expertise for the physiognomy of other-race faces) or social cognition (viewers' motivations vary across in- and out-group faces; Young, Hugenberg, Bernstein & Sacco, 2012, Personality and Social Psychology Review, 16(2), 1-27). Only social cognition can explain other face recognition biases where groups do not differ physically (e.g., own-university). The degree that social cognition and perception combine to explain the own-race bias is assessed by comparing eye movements leading to the own-university versus own-race bias. Our students completed two face recognition tests using faces of own/other race and own/other university. All faces were previously unknown and were labelled own/other university randomly. Patterns of recognition accuracy confirm the previously reported own-race and own-university biases. Previously untested, differences in eye movements and pupil size were observed for own- and other-university faces. Importantly, patterns of eye-position revealed some bias-specific differences. However, common patterns across both biases of own-group dependent eye movements provide an index of non-perceptual mechanisms shared by these two own-group recognition biases.

◆ **Face perception between race, gender and familiarity**

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Although many studies examined phenomena that occur during face processing, there are still a number of open questions. This study investigated own-race bias (ORB), own-gender bias (OGB) and importance of the factor of familiarity as well as their potential mutual relations, for the first time on Serbian population. Subjects (60, Caucasian, females) took part in three experiments. In all experiments the old/new task paradigm was used. Consistently with previous finding, ORB was demonstrated. Caucasian faces were recognized with higher accuracy comparing to African faces ($Z=3.29$ $P< 0.01$) or Asian faces ($Z= 2.59$ $P< 0.01$). After introduction of famous people' faces, effects of ORB for unfamiliar faces significantly decreased. Nevertheless, effect "seen before" was still present. This result suggest that, although effect of ORB are decreased, there is still better recognition for own-race faces, further implicating that ORB might overweight familiarity. For OGB results were ambiguous. OGB was consistently demonstrated only for own-race faces. Interestingly, own and other-race male faces were equally good recognized. These finding suggest that, at least partially, ORB could be explained by occurrence of OGB. This research was supported by Ministry of Education and Science, Grants No. 179033 and III47020.

◆ **Objective measurement of face discrimination with a fast periodic oddball paradigm**

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We present a novel paradigm using fast periodic oddball stimulation to objectively and efficiently quantify individual face discrimination. We recorded EEG in 20 observers presented with 60-second sequences containing a base-face (A) contrast-modulated at a frequency of 5.88 Hz. Oddball-faces (B,C...) were introduced at fixed intervals (every 5th stimuli or 5.88 Hz/5 = 1.18 Hz: AAAABAAAACAAAAD...). Face discrimination was indexed by responses at this oddball frequency. High-level face processing was targeted by manipulating size (face size randomly varied every 5.88 Hz cycle), orientation (upright vs. inverted, Experiment 1) and contrast (normal contrast vs. contrast-reversed, Experiment 2). In both experiments, normal faces evoked highly significant responses at 1.18 Hz and its harmonics on right occipito-temporal channels. Inversion and contrast-reversal significantly reduced oddball responses, while the basic 5.88 Hz response did not differ between conditions. In Experiment 3, we tested prosopagnosic patient PS [Rossion et al., 2003, Brain, 126:2381-95], who is specifically impaired at face discrimination [Busigny et al., 2010, Neuropsychologia, 48:2051-67]. Although PS' basic response to faces was similar to young controls (N=11), her right occipito-temporal oddball response was absent. These observations underline the usefulness of fast periodic oddball stimulation to measure face discrimination on a neural level.

POSTERS : MOTION

◆ **Functional characteristics of the receptive field of looming detectors for perception of**

123 **motion in depth**

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Adaptation to a stimulus that changes size produces the aftereffect of motion in depth. Two vertical lines moving in opposite directions and an orthogonal pair of lines in relative motion produce the aftereffect of motion in depth (Susami, 1994, 17ECVP Supplement, 38-39; 1995, 18ECVP Supplement, 112). These results show that relative motion (anti-phase components; Regan et al., 1979, Scientific American, 241, 136-151) is important for looming detection in the perception of motion in depth. In this study, we examine the functional characteristics of the receptive field of the looming detector caused by the motion-in-depth aftereffect by using two adaptation lines moving in opposite directions. When the distance between the two moving lines increased, the motion-in-depth aftereffect decreased, and disappeared at 3 degrees or so. When the two test stimuli were presented to the two adaptation areas with a test stimulus between them (within the receptive field), the motion-in-depth aftereffect also occurred in the center test stimulus. These results suggest that the looming mechanisms detect not the optical flow of the whole retinal image while in self-forward motion but the retinal area of the moving object in depth; moreover, these mechanisms process the inside of the receptive field of the object.

◆ **Motion Processing based on spatio-temporal receptive fields with biphasic temporal response property**

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Decoding and understanding motion starts already in the retinal ganglion cells and in the lateral geniculate nucleus (LGN) as they provide a particular temporal characteristic for the motion selective cells in the primary visual cortex (V1). For natural images the visual information consists of a stream of time-varying brightness values and motion as well as its components, velocity and direction, have to be computed from this stream. Here we introduce a neuro-computational model of LGN that is based on space-time dependent receptive fields with biphasic temporal response properties. The spatial structure of the receptive fields are classic center surround ones as found in LGN cells. This spatial structure is modulated by a biphasic temporal function which has been described in visual areas, e.g. LGN, primary visual cortex (V1). These biphasic neural response properties lead to a complete change of the spatial structure from on-center to off-center characteristic and vice versa. However, different from previous models the temporal characteristic has not been pre-defined by a fixed filter function, but it is the result of the computation induced by the temporal changes. We used this model to fit the spatio-temporal receptive fields of LGN cells with different stimulation protocols.

◆ **Suppression of motion perception through non-linear retinal processing**

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Fixational eye movements shift the visual image across the retina during fixation. These movements can be well above thresholds for visual motion detection, yet produce little or no motion percept. This implies the existence of mechanisms for inhibition of motion signals due to eye movements. We describe a model in which such perceptual suppression can arise as a result of non-linear processing in Parasol-type retinal ganglion cells. These cells implement a non-linear spatial integration, corresponding to individual rectification of bipolar cells within their dendritic field (Hochstein & Shapley, 1976). Due to their highly transient, phase invariant spiking, these cells seem well adapted to signal motion onset and saccades. The model uses these cells as input to a motion detection mechanism which distinguishes between local and non-local motion at the retinal level. When tested with stimuli containing both local differential motion of an object against background, and global shifts of the stimulus which mimic micro-saccades, this model successfully suppresses detection of saccadic movements, while still enabling accurate tracking of object motion. Thus, the model can account for the inhibition of motion percepts arising from global shifts due to eye movements, even in the absence of any reliable information about eye position.

◆ **An Model for Non-Retinotopic Processing**

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The visual system transforms the retinal image of moving objects into an object-centered reference frame. For example, a person in a moving train appears to walk slowly, and not with the added speed of the train, i.e., train speed is discounted. Object-centered motion cannot easily be explained by classical motion models because they can only pick out retinotopic motion. We propose an alternative, two-step model in which motion is computed in a nested, hierarchical fashion. First, we compute the main object motion (e.g. the train), forming edge-based objects using the Gestalt grouping principles of proximity and good continuation. Within this reference-frame, we then compute the motion of other elements/objects (e.g., the person in the train). To this end, the model tracks the objects and parts across time, discounting for the objects' motions when computing their parts' motions. Using this simple procedure, our current model outperforms all prior non-retinotopic processing models. As an example, we show how retinotopic motion, non-retinotopic motion, and the transition between the two can be explained with the Ternus-Pikler Display (TPD).

◆ **How are non-retinotopic motion signals integrated? -A high-density EEG study**

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Objects moving in the visual scene cause retinal displacements that are not the result of motor commands and thus cannot be accounted for by efference copies. Yet, we easily keep track of moving objects even without following them with our gaze. Here, we investigated the neural correlates of non-retinotopic motion integration using high-density EEG. We presented three disks that either flickered at the same location (retinotopic reference frame) or moved left-right in apparent motion, creating a non-retinotopic reference frame in which the features of the disks are integrated across retinal positions. In one disk, a notch was either changing positions across frames in a rotating fashion, or stayed in the same position. The notch then started or stopped rotating after a random number of frames. We found stronger EEG responses for rotating than for static notches. In the novel state (first frame of rotating or static), this effect occurs in the N2 peak and resembles a motion-onset detection signal. Inverse solutions point to the right middle temporal gyrus as the underlying source. Importantly, these results hold for both the retinotopic and the non-retinotopic reference frames, indicating that the rotation encoding is independent of reference frame.

◆ **The contribution of peripheral flow to flow-parsing**

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The Flow-Parsing Hypothesis (FPH; 2005, Curr Biol, 15, R542-R543) suggests that moving observers parse retinal motion into self and object motion to reveal scene-relative object movement. Recently, we investigated the contribution of peripheral flow to this process (Rogers et al, 2012, Perception, 41, 1524). We demonstrated that peripheral radial flow, presented on monitors at the side of the head, produced a signature bias in perceived trajectory for an object in central vision. Here, we examined the role of peripheral flow during lateral translation and yaw rotation with a variant of Warren and Rushton's task (2007, J Vis, 7, 1-11). Fourteen observers fixated a central stereoscopic target at a distance of 80, 95, or 110cm, which moved upwards. Simultaneously, background visual flow indicated either sideways translation or yaw rotation. Participants reported perceived target trajectory by orienting a line. As in the original study, in accordance with the FPH, target depth influenced perceived target trajectory differently for rotating than translating self-motion and the presence of stereo cues improved performance. The addition of peripheral flow did not produce a systematic improvement in performance, suggesting that the contribution of peripheral flow to the flow parsing process is limited during lateral translation and yaw rotation.

◆ **Motion spatially facilitates the detection of static objects**

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There is strong evidence that motion elicits a fast spreading neural activity with a short neural latency [Paradis et al, 2012, Front. Hum. Neurosci. 6:330]. Motion (facilitated) signals are sent to the neighboring neurons with the receptive fields co-aligned in the visual space, producing a facilitation effect for the future locations that are likely to be activated in the near future by the moving object. Neural facilitation also depends on the contrast and distance of the object. In our experiment, we addressed spatial facilitation provoked by co-aligned or misaligned moving Gabor patches. The Gabor moved in the direction of one of two static flashes and the onset of that (facilitated) flash was varied according to the constant stimuli method. We found an illusory motion effect between two static flashed stimuli. The facilitated flash was perceived earlier when appeared ahead of the co-aligned moving Gabor patch. Stimuli located ahead of collinear motion were consistently detected faster, and for this reason, an illusory motion from one static flash to the other was observed even when presented simultaneously. Our psychophysical findings can be explained as the result of a neural facilitation provoked by motion.

◆ **Second-order motion processed by the first-order motion system at high carrier contrasts**

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Previous studies have shown that contrast-defined motion is processed by a feature tracking motion or an energy-based motion system depending on whether the carrier contrast is low or high, respectively. The fact that global distortion products could not explain the energy-based processing of contrast-defined motion has been taken as evidence of a dedicated second-order motion system. However, we [in press, Journal of Vision] recently revealed the existence of nonlinearities that have not been considered before and can enable the first-order system to process contrast-defined motion by introducing residual distortion products (i.e. local luminance artifacts of both polarities). Here we evaluated the impact of a static luminance pedestal on luminance- and contrast-defined motion processing. For various carrier contrasts, the contrast of the luminance pedestal was adjusted to affect luminance-defined motion thresholds by a factor of about 2. The luminance pedestal was found to affect contrast-defined motion thresholds by a factor near 2 when the carrier contrast was high, but had little impact when it was low. We conclude that contrast-defined motion with high contrast carriers was processed by the first-order motion system, not a second-order motion system. Our results question the existence of a dedicated second-order motion system.

◆ **Paradoxical perception of shape in motion displays**

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We used ambiguous motion displays in which several motion quartets (Ramachandran & Antsis, 1983, Nature, 304:11, 529-531) were arranged on an invisible circular contour. The displays could be perceived either as "element motion" of dots within the quartets or as "object motion" of dots between the quartets that invoked perception of a large moving object. We asked if shortening the distances within the motion quartets would resolve the ambiguity in favor of element or object motion. From the Gestalt principle of proximity we expected a shift towards element motion, but characteristics of human spatiotemporal contrast sensitivity (Gepshtein & Kubovy, 2007, Journal of Vision 7(8):9, 1-15) predicted a shift towards object motion. The results were consistent with the latter prediction: reducing the distances within the quartets made the object motion increasingly likely. Thus conditions for perception of objects in dynamic scenes agree with characteristics of human spatiotemporal contrast sensitivity and disagree with the Gestalt principle of proximity. The work was supported by Odysseus research grant awarded to CvL from the Flemish Organization for Science, and National Science Foundation award 1027259 to SG.

◆ **Perceived Rotation Axis for Specular, Textured, Uniform and Silhouette Objects**

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Previously we showed that observers made larger errors in estimating the rotation axis of shiny objects than for matte, textured objects (Kucukoglu, 2010). However, to analyze observers' estimates with respect to veridicality is limiting in terms of understanding how surface reflectance and texture biases the estimate. Here we systematically investigate how observers' perception of rotation axis elevation and azimuth depends on surface material. Stimuli were isotropic objects of four different material categories that rotated in depth through 40 degrees. Rotation axes were systematically sampled from the unit hemisphere, with elevations 10, 20, 30, 50, and 70 degrees and azimuths 0-330 degrees in 30 degree increments. Observers (N=7) repeated every material-rotation axis direction combination once. Modeling the data using the Kent distribution we computed the centroid and spread for observers' estimates for each sampled rotation axis direction. For rotation directions near the line of sight observers' settings across material conditions deviated little form each other in centroid location and spread. For elevations larger than 30 degrees observers underestimated the elevation across all material conditions, however, azimuth of the centroid, mode and spread differed substantially between surface material conditions. We account for these differences with a structure from motion approach.

◆ 133 **Integration of object motion across apertures during tracking eye movements: perceptual and oculomotor measures**

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Local motion signals need to be integrated across space to recover objects' direction of motion. We investigated previously reported directional asymmetries in perceiving global motion during pursuit eye movements [Souto D and Johnston A 2011 ECVP]. Observers had to track or fixate a dot surrounded by a ring of randomly oriented Gabors and discriminate the direction ($\pm 10^\circ$) of a brief episode of global motion. Higher signal to noise ratios were required for direction discrimination with motion opposite to the eye movement as compared to motion in the same direction, or with a stationary display. Oculometric measures were derived from horizontal eye velocity change induced by global motion. In contrast to perception, eye movements indicated lower or similar thresholds for motion opposite to the pursuit direction compared to same direction or fixation. We propose that higher perceptual thresholds for opposite motion arise from a deficit in parsing signal from noise, since it is specifically required for the perceptual task but not for generating a horizontal ocular response. Relatively better perceptual integration for same direction motion signals might have a functional role, since a rigid object' contours move in the direction it is tracked, unlike background or occluding features.

◆ 134 **Global Pooling of Transformational Apparent Motion**

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Transformational apparent motion (TAM) is a visual phenomenon highlighting the utility of form information in motion processing. In TAM, smooth apparent motion is perceived when shapes in certain spatiotemporal arrangements change. It has been argued that TAM relies on a separate high-level form-motion system, as certain spatial arrangements of TAM violate low-level motion energy models of vision. As yet, however, few studies have examined how TAM relates to the previously described motion system. We report a series of experiments showing that like, conventional motion stimuli, multiple TAM signals can combine into a global motion percept. After controlling for motion energy, we show that TAM appears to pool using a separate motion system than the motion energy system, that has less tolerance to noise. This system is relatively weak and is easily overridden when motion energy cues are sufficiently strong. We conclude the ability to holistically integrate multiple TAM signals demonstrates this high-level form-motion information enters the motion system by at least the stage of global motion pooling.

◆ 135 **A magnetoencephalographic study on the components of event-related fields in an apparent motion illusion with changing stimulus shape and color**

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We explored an apparent motion illusion (beta movement) by obtaining neuromagnetic responses from event-related fields (ERFs). Two stimuli, presented horizontally 10 degrees apart, were used. The first stimulus (S1, a white circle), presented for 16.7 ms, was followed by the second stimulus (S2, a white triangle in Experiment 1, shape-changing condition; and a red circle in Experiment 2, color-changing condition) with three conditions of stimulus-onset asynchrony: (a) at 16.7 ms, the two stimuli were almost simultaneously seen; (b) at 83.3 ms, the motion illusion was optimally perceived; and (c) at 550.0 ms, the stimuli appeared isolated. We applied minimum current estimates (MCEs) to obtain the source activity of ERFs for beta movement, and calculated the average amplitude of five 100-ms epochs after S2 onset. The optimal condition showed MCE amplitudes larger than those in the simultaneous condition at the second 100-ms epoch in both central and parietal areas in Experiment 2, but not in Experiment 1, thereby suggesting that the motion components of MCEs clearly emerged from this epoch for the color-changing condition. Thus, the neuromagnetic activity of beta movement may be evoked for the color-changing condition more easily than for the shape-changing condition and may originate in centro-parietal areas.

◆ **Perceived global motion-dependent activity in human early visual cortex under two attentional conditions**

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When a two dimensional silhouette of a "Pac-Man" oscillates about its center, the local motion signals are solely determined by the Pac-Man's "mouth". Nevertheless the surface is perceived to oscillate as a whole. Here we measured the cortical activity using functional magnetic resonance imaging (fMRI) while observers were fixating at the oscillating Pac-Man's center, under two attentional conditions. In one condition participants performed a demanding fixation task, in the other condition they viewed the stimulus passively while maintaining fixation at its center. The amplitude of oscillations were adjusted such that the local motion signals were restricted to the right visual field, therefore in the null hypothesis we expected to find no activity in the right hemisphere visual areas. In the passive view condition we found that the fMRI signal in most of the early visual areas in the right hemisphere was correlated with the perceived global motion, and rejected the null hypothesis. In the fixation task condition the perceived global motion-dependent activity was limited to areas V3A/B, LO1 and MT+. These results provide evidence of inter-hemispherical modulation of early cortical activity due to the perception of global form and motion.

◆ **Global motion perception thresholds of good and poor readers**

137 E Kassaliete, A Krastina, J Blake, I Lacis, S Fomins (Department of Optometry and Vision Science, University of Latvia, Latvia; e-mail: evita.kassaliete@lu.lv)

Global motion perception is the perception of coherent motion in a noisy motion stimulus and it is one of the most important components in visual perception. This task strongly involves extrastriate brain areas, particularly V5/MT, where the dorsal stream dominates [R.Laycock et al, 2006, Behavioral and Brain Function, 2(26), 1-14]. Aim of this study was to determine global motion perception thresholds of typically developing children with different reading skills, using modified random dot kinematograms (RDK). 2055 children in 14 age groups from 6 to 19 years participated in the study. Stimulus consisted of moving 100 black dots (7 arc min), displayed for 1.7 seconds on the 12° white background of rectangular form. Signal and noise dots moved with identical velocities of 2, 5 or 8 deg/s. Global motion detection threshold decreased with age for all dot velocities. Motion perception threshold was significantly higher at 8deg/s velocity ($p<0,0001$), with mean value of 51,3%±0,6, while for 2 and 5 deg/s mean values were 31,7%±0,6 and 33,7%±0,6. Motion perception for poor and good readers differed only for velocity of 2deg/s ($p=0,045$). To determine reading skills we used modified One minute reading test.

◆ **Characterisation of the Dorsal and Ventral Pathways Using External Noise Paradigm**

138 M Joshi, S T Jeon (Department of Vision Sciences, Glasgow Caledonian University, United Kingdom; e-mail: mahesh.joshi@gcu.ac.uk)

Current study evaluated the sensitivity to global motion and form perception which are presumably processed by two distinct visual pathways – dorsal and ventral respectively [Ungerleider and Mishikin, 1982, in: Analysis of Visual Behavior, Cambridge, MIT press] – in varying noise levels. We used Glass pattern [Glass, 1969, Nature, 223, 578-579] and random dot kinematogram (RDK) to evaluate and compare each pathway directly by making the experimental parameters as equivalent as possible in both tasks. Four normal observers discriminated global direction of 500 moving dots or overall orientation of 250 dipoles from 12 o'clock. For each trial, direction/orientation of a dot/dipole was sampled from a normal distribution with one of the eight predetermined direction/orientation variances ranging from ±1° to ±120°, whereas the mean direction/orientation to be discriminated was determined by the 3-down-1-up staircase. When plotted against noise levels, the thresholds remained constant at low variances and started to increase as variance increased. Except for one observer, individual thresholds for Glass pattern were consistently higher than those for RDK across the different variance levels; mean log threshold ratio (Glass/RDK) was 1.503±0.24. In the future, functional mechanisms of both pathways will be quantitatively modelled with consideration of noise.

◆ **An explanation of why component contrast affects perceived pattern motion**

139 L Bowns (School of Psychology, The University of Nottingham, United Kingdom; e-mail: l.bowns@nottingham.ac.uk)

Component contrast is an essential element in computing spatio-temporal motion energy, and has been shown to bias perceived motion, (Thompson, 1982, Vision Research, 22 (3), 377-380). More recently, (Champion et al, 2007, Vision Research, 47 (3), 375-383) concluded that two-dimensional features in the stimulus was the explanation for this motion bias. Here a method was used that eliminated two-dimensional features as the source of the bias. (Bowns, 1996, Vision Research, 36 (22) 3685-3694) showed that Type II plaids shifted from the intersection of constraints direction (IOC) to the vector average direction (VA) as a function of the speed ratio of the components at short durations. It was therefore argued that if the speed of the components could be increased or decreased by varying the component contrast, then this should be reflected in the change from the IOC to the vector average. Perceived direction was markedly affected by contrast. Contrast can bias perceived motion even when two-dimensional features are controlled for, but the source of the bias is not from computing the IOC from motion energy, or by tracking two-dimensional features, but instead is predicted by the Component Level Feature Model developed to be predominantly invariant to contrast.

◆ **Effects of orientation and speed on direction perception during occluded target motion**

140 A Hughes, D Tolhurst (Department of Physiology, University of Cambridge, United Kingdom; e-mail: aeh60@cam.ac.uk)

We have previously shown that visual predictions of the direction of a moving Gabor can be biased by the motion of the stripes within it (Hughes & Tolhurst, 2012, Perception, 41(12), 1519). Here we show that the orientation of static stripes can also cause perceptual biases. Observers viewed a Gabor target with oblique stripes moving across a CRT display with a linear trajectory randomly chosen within 18 degrees of the horizontal. After occlusion, they predicted where it would later cross a vertical line using a numerical scale bar. We show that speed of lateral movement has an important effect on direction perception; at high speeds, patches with oblique stripes that pointed upwards relative to the direction of lateral motion were perceived to cross higher than patches where the stripes pointed downwards relative to the direction of motion. This effect occurred only at speeds at or above the critical speed required for 'motion streaks' (Geisler, 1999, Nature, 6739, 65-69), suggesting that it may be caused by a similar orientation specific mechanism. However, at lower speeds, the pattern of perceived biases was reversed. We propose that the different patterns of results may reflect different motion detection processes that operate at different speeds.

◆ **Motion extrapolation: evidence for an internal representation of motion during transient**

141 **absence of stimulus**

M Aliakbari Khoei, G S Masson, L U Perrinet (Institute Neuroscience de la Timone, Aix-Marseille University - CNRS, France; e-mail: mina.aliakbari-khoei@univ-amu.fr)

During normal viewing, the continuous stream of visual input is regularly interrupted, for instance by blinks of the eye. Despite these frequents blanks, the visual system is able to maintain continuous representation of motion, for instance by maintaining the movement of the eye such as to stabilize the image of an object. This ability suggests the existence of a generic neural mechanism of motion extrapolation to deal with fragmented inputs. In this study, we have modeled how the visual system may extrapolate the trajectory of an object during a blank using motion-based prediction. This implies that using a prior on the coherency of motion, the system may integrate previous motion information even in the absence of stimulus. Unlike most of previous modeling studies, we have considered position of motion as an important piece of sensory information in synergy with velocity information. In that perspective, we have studied the role of prediction in position and velocity separately and together. We found that an internal representation of position and velocity of motion during absence of sensory input helps quick recovery of tracking after reappearance of stimulus. This recovery is slower and less accurate when prediction is only inferred in the velocity domain.

◆ **The effect of dynamic dots texture on motion extrapolation**

142 L Battaglini, G Campana, C Casco (Department of General Psychology, University of Padua, Italy; e-mail: lucabni@hotmail.com)

People are able to judge the current position of occluded moving objects. This operation is known as motion extrapolation. It has been suggest that motion imagery associated with a movement of visuospatial attention is involved in this task. We run two experiments to underlie the importance

of motion interference on motion imagery. Participants had to predict the position of occluded target indicating the time to contact (TTC) with the end of the occluder. The occluder was a texture of randomly positioned dots. In the first experiment the dots moved either in the same way of the moving target or in the opposite direction. Results showed longer TTC when dots moved in opposite direction, suggesting an interference of dots texture direction of motion when incongruent with the visuospatial tracking direction. In the second experiment the dots were either static or dynamic (each dot moved in a random direction). Results showed shorter TTC with dynamic dots texture. The TTC reduction cannot simply be the result of visual noise added on motion extrapolation. More likely, randomly moving dots texture "speeds-up" motion extrapoation. These results are coherent with fMRI findings of an activation of motion areas (MT) during extrapolation of occluded motion.

◆ **Identification of Surface Reflectance from Motion Cues in Fovea and Periphery**

143 H Camalan[1], A Jain[2], Q Zaidi[2], K Doerschner[1] ([1]Department of Psychology & UMRAM, Bilkent University, Turkey; [2]Graduate Center for Vision Research, SUNY College of Optometry, NY, United States; e-mail: camalanhuseyin@gmail.com)

Doerschner et al. (2012) demonstrated that image motion can be a significant factor in the perception of objects' material qualities. Specifically, they proposed optic-flow based cues that predicted when observers would perceive a given object as shiny or as matte. These results were consistent with te Pas et al. (1996) who showed that observers are sensitive to flow field properties not only at large but also at small scales, as they may occur in the context of object recognition tasks. Interestingly te Pas et al. (1996) also found that observers' performance did not decline when foveal information was not available. If optic flow elements can be extracted by the visual system from the periphery and if these elements in part subserve motion-based surface material perception then surface reflectance recognition performance should not decline with eccentricity. We examined this hypothesis using a 2IFC task. Stimuli were movies of matte-textured and specular novel-shaped objects rotating in depth presented either at the fovea or at 4 degrees eccentricity. Observers indicated whether the first or second object was more shiny. Our results suggest that optic-flow based cues to surface material reflectance identification must also be available in the peripheral visual field.

◆ **Interaction improves judgements of surface reflectance properties**

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Rendering materials on displays becomes ubiquitous in industrial design, architecture and visualisation. Previous studies measured the influence of disparity, motion and colour on the perception of gloss in renderings [Nishida et Shinya, 1998, Jour. Opt. Soc. Am. A, 12 2951–2965] [Wendt et al., 2010, Journal of Vision 10(9):7 1–17] . Observers passively experienced motion in those studies, while users can interactively move the rendered surfaces in most design applications. We investigate, whether observers actively exploring rendered stimuli judge their surface reflectance properties differently than observers passively watching renderings. In the present study, we compare judgements of rough surfaces differing in gloss by interacting and passive observers. Various renderings of a surface geometry digitized with a 3D laser scanner had to be attributed to the most similar of real samples. We found that inter-observer reliability was significantly higher for interacting observers. The claim is supported by several indices of inter-observer reliability. Our results also shed light on the open questions of [Wendt et al., op. cit.] with regard to motion. The perpetuity of motion in their experiments could negatively impact observer performance.

POSTERS : VISUAL SEARCH

◆ **Biased visual search in a homogenous background**

145 C Paeye, A Schütz, K R Gegenfurtner (Department of Psychology, Justus-Liebig-University Giessen, Germany; e-mail: celine.paeye@psychol.uni-giessen.de)

To account for eye movement strategies during visual search, Najemnik and Geisler [2005, Nature, 434, 387-391] elaborated a Bayesian model that updates its representation about the target location to plan the next fixation so as to maximize the information collected. Their model describes human performance well. We tested whether introducing a target location bias would affect the visual search strategies of naïve participants. An optimal observer would use such prior information to make the search more efficient. We presented a target four times more often in one quadrant of a 1/f background

noise. We tested different target visibilities (d' between four and one). The search efficiency was high (median fixation counts from three to ten, median detection times from two to five seconds). However, only three out of six participants modified their saccade sequences in favor of the quadrant containing the target more often. This is in contrast to recent studies observing statistical learning when subjects have to identify a target among several distinct items [eg. Jiang et al., 2013, J Exp Psychol, 39, 87-99]. Presumably it is more difficult to induce statistical learning when the target can appear at any position in a homogenous background.

◆ **Comparison between a global and a limited sampling strategy in size-averaging a set of items**

146 M Tokita, A Ishiguchi (Ochanomizu University, Japan; e-mail: tokita.midori@ocha.ac.jp)

Many studies have shown that people can accurately perceive and estimate the statistical properties of a set of items (Ariely, 2001, Psychol Sci, 12(2), 157-162; Chong & Treisman, 2005, Vision Res, 45(7), 891-900). As the accuracy with which people can judge the mean size of a set is consistent across set size, some have proposed that average size can be computed in parallel across all items. At the same time, it has been shown that the accuracy can be predicted by a strategy of sampling the sizes of limited number of items in a set using focused attention (Myczek & Simons, 2008, Percept Psychophys, 70(5), 772-788). In this study, we tested two ideal observer models (i.e., a global and a limited sampling models) to compare them with human observers. The global averaging model posits that people average over all items in a set: the limited sampling model posits that people sample two to four items randomly chosen form a set. In our behavioral experiments, participants were asked to estimate the average size of the items in a set and compare it to a reference item. The results implied that the limited sampling model could predict behavioral data.

◆ **Attentional shifts during visual search are accessible to introspection**

147 G Reyes[1], J Sackur[2] ([1]Université Pierre et Marie CURIE, France; [2]LSCP, École Normale Supérieure, France; e-mail: gureyes@uc.cl)

Recent advances in metacognition have shown that participants are introspectively aware of different cognitive states. Here we set out to expand the range of introspective knowledge by asking whether participants could introspectively access the attentional shifts in two types of visual searches: feature and conjunction searches. To this end, we instructed participants to give, on a trial-by-trial basis, an estimate of the number of elements scanned before the perceptual decision. In addition, we collected eye movements, so as to distinguish overt and covert attentional shifts. Results show that participants gained access to the nature of the search process through introspective estimation of the number of attentional shifts. In a first experiment we allowed eye movements and analyses showed that participants were able to report the number of items scanned during the search. However, mediation analyses showed that this estimation tracked the search time and the number of saccades. In a second experiment we controlled voluntary eye movements, and showed that introspection presented the same pattern. This suggests that participants were indeed able to monitor covert attentional shifts. Additional experiments, were we manipulated attentional shifts with exogenous cues, confirmed that introspection is determined by the number of attentional shifts.

◆ **Neural bottlenecks in concurrent multi-item visual search**

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Psychophysical data suggest that concurrent visual search for two items is impossible, since only one item in working memory (WM) can function as search template at a time [Houtkamp and Roelfsema, 2009, Psychological Research, 73, 317–326]. Here, we studied the neural correlates of this multi-item search limitation using fMRI (3T, n=8, TR/TE = 1.25s/30ms). Participants had to detect a face or a house (uni-search), or a face and house (dual-search) in a stream of superimposed face and house images. Psychophysical results (n=16) confirmed that in the dual-search condition, the two target representations in WM could not guide attention simultaneously. This limitation was reflected in face- and house-preferring visual areas, where dual-search elicited lower responses than uni-search for the preferred category. In contrast, dual-search did induce stronger activation in a frontoparietal network involved in storage and control of items in WM. Our current investigations of the interaction between these frontoparietal and visual activations may provide more insights into the neural bottlenecks causing the limited capacity of attentional guidance by WM.

◆ **Does gaze-contingent limited view modify spatial contextual cueing in visual search?**

149 X Zang, L Jia, H J Müller, Z Shi (Department of Psychology, LMU Munich, Germany; e-mail: xuelian.zang@campus.lmu.de)

Participants were faster in respond to repeatedly-presented displays compared to non-repeated displays during visual search. This phenomenon has been known as contextual cueing (Chun and Jiang, 1998, Cognitive Psychology 36, 28-71). The mechanisms of global and local context contributing to contextual cueing are still under debated (Kunar et el., 2006, Percept Psychophys, 68(7), 1204-1216; Song and Jiang, 2005, Journal of Vision, 5, 322-30). In most studies on contextual cueing, global (e.g., the whole visual display) and local (e.g., a small region around the target) context were not explicitly separated and often correlated with each other. In the present study, two visual search experiments with gaze-contingent limited view were conducted, in which, both repeated old displays and non-repeated new displays are only visible inside a limited gaze-centered area. Classical contextual cueing was manifested for large viewing window (12°), but not for small viewing window (8°). Interestingly, contextual cueing effect was regained for the latter when the gaze-contingent limited view was removed in the test phase. Oculomotor behavior showed that the number of saccades decreased and fixation duration increased for the old displays. Our findings suggested gaze-contingent limited view didn't affect spatial context learning, rather impeded the retrieval of the learned context.

◆ **Does chemotherapy lead to a visual search deficit?**

150 T Horowitz (National Cancer Institute, National Institutes of Health, MD, United States; e-mail: todd.horowitz@nih.gov)

There is now evidence that chemotherapy leads to persistent cognitive deficits. A recent meta-analysis of 17 studies concluded that chemotherapy resulted in persistent visuospatial, but not attentional deficits [Jim, H. S., et al, 2012, Journal of Clinical Oncology, 30(29), 3578-3587], relative to breast cancer patients not treated with chemotherapy. However, their sample of 43 "attentional" tests included only 16 valid attention tests. I reclassified their measures, identifying 11 studies reporting 5 measures with visual search components: letter cancellation (D2 test, Ruff 2 & 7); Trail Making Task (TMT) versions A and B; spatial configuration search (FEPSY Visual Search). A new meta-analysis of this set yielded a summary effect size estimate of -0.058 (95% CI: -0.143, 0.027; p = .18; negative indicating chemotherapy deficit). I then analyzed the TMT tasks separately, in order of increasing visual search relevance. Effect sizes were -0.106 (-0.256, 0.0449; p. = .17) for TMT B, and -0.145 (-0.277, -0.012; p = .03) for TMT A. This suggests that chemotherapy leads to persistent deficits in visual search. However, this conclusion is based on coarse-grained neuropsychological tests. There is a critical need for studies on the effects of chemotherapy using more sensitive tests of visual search and attention.

◆ **Proportion estimation among subsets of features and conjunctions**

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Summary statistics is an efficient code that allows representing multiple objects despite severe attentional limitations. Treisman claimed that we can easily represent statistical properties within overlapping feature-marked but not conjunction-marked subsets [Treisman, 2006, Visual Cognition, 14(4-8): 411–443] since conjunctions require focused attention to be bound properly. We tested this prediction thoroughly in three experiments modifying one of Treisman's experiments. Observers were briefly presented with sets of red, green, or blue Ts, Xs, and Os (either all 3×3 or only arbitrary 2×2 features were used to impose different working memory load) and were to evaluate the proportion of precued or postcued feature (color or shape) or conjunction. Our results showed that both features and conjunctions were estimated equally precisely, which is inconsistent with the results reported by Treisman; though increased number of features led to less accurate evaluation due to certain limitations of visual working memory. Evaluation was more precise in precue condition, except blocking color, shape and conjunction trials, when precue did not affect accuracy regarding features but not conjunctions. This could be because three particular features do not exceed working memory capacities [Halberda et al., 2006, Psychological Science, 17(7): 572-576) and are evaluated easily even when not cued.

◆ **Attentive Pop-Out: Spatial Asymmetries in a Visual Search Task**

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In literature the existence of different kinds of popouts, the preattentive and attentive popouts, which reveal different attentional resources has been suggested (VanRullen et al., 2004, Journal of Cognitive Neuroscience, 16:1, 4-14). We aimed at investigating the existence of left-right asymmetries in visual search paradigm (Poynter et al., 2012, Laterality, 17(6), 711-726) in the case of attentive popout. We administered to 41 psychology students a detection task in which an "L" target stimulus, half-times displayed to the left side of the monitor and half-times to the right, could or could not be present. The number of distractors ("X" stimuli) was varied (2, 4,8 and 16) and presented in a random order. The results show the absence of the popout effect: reaction times increased with the number of distractors not only in the absence of the target, but also when it was present. Moreover, we found a different trend of RT increase in function of number of distractors depending on the target spatial position, i.e. in the left or right part of the screen. The results will be discussed in the light of the relationship between perception and attention.

◆ **Attention and memory resolution in hierarchical search: Behavioral and diffusion model**

153 **evidence**

Q-Y Nie, H J Müller, M Conci (Department of Psychology, LMU Munich, Germany; e-mail: qiyang.nie@psy.lmu.de)

Objects can be represented at multiple hierarchical levels, but typically, more global object levels receive precedence over more local levels(Navon, 1977). Here, we explored the resolution of attention and memory across global and local hierarchical object levels using a visual search task with Navon letters as targets and non-targets (Deco & Heinke, 2007). Our results show that search for targets defined at the global level was more efficient than search for local-level targets. Moreover, this global precedence effect on attention was transferred to memory, as an analysis of cross-trial contingencies revealed priming to occur only for global targets but not for local targets. Subsequent experiments manipulated the prevalence of global and local targets. When local targets were presented more frequently than global targets (i.e. local targets on 75% of all trials), global precedence was overall reduced and priming occurred at both object levels. In addition, when systematically changing the prevalence of global and local targets throughout the experiment, attention showed a dynamic hierarchical adjustment according to target prevalence, but memory remained constant. In sum, our findings demonstrate that the resolution of attention and memory both reflect hierarchical object structure, but both processes show different underlying dynamics of object-level adjustment.

◆ **Feature search in 2½D subjective surfaces: is it pre-attentive?**

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We studied visual feature search in two arrays of elements composed of identical properties. One composed of 2D elements (a cross among rings), perceived as 2D fronto-parallel surface. The other was the perceived 2D surface viewed from an elevated eye-position, composed of coherent volumetric elements lying on 2½D subjective surface. Contrary to target "pop-out" and no set-size in searching the 2D array, Treisman's "feature integration theory" would regard search in the 2½D array conjunctive, since the 2½D elements differ in angular size, shape, and density. 10 participants searched both arrays (24 or 42 distractors), and 2½D scattered control arrays, while measured for separated Reaction Time ("view period" VP from trial-activating key press to release, and "Response-Period" key release to choice reaction), and eye-movements. Repeated-measures ANOVA revealed no significant difference between the 2D and 2½D conditions, but significantly longer VP's during 2½D-controls. Detection efficiency was not affected by set-size. Less than three saccades were sufficient for target detection in both 2D and 2½D surfaces, significantly less than needed for the 2½D controls. Our results indicate that search in the 2½D surface preserved the 2D pre-attentive properties. Our results are discussed with reference to the rivers -hierarchy theory (Hochstein and Ahissar 2002).

◆ **Hemispheric specialisation when searching in real-world scenes: an eye-movement approach**

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We studied the contributions of the cerebral hemispheres to real-world visual search by examining oculomotor behaviour. The target template (picture or name) was presented centrally and the scene appeared after a 100 or 900-ms ISI. The target object was lateralised in its left or right half, in order to be presented initially to the Right (RH) or the Left Hemisphere (LH), respectively. With a picture template, the first saccade was faster in the left (lvf) than in the right visual field (rvf). It was also faster with a picture than a word template, but only in the lvf, and with the long than the short ISI, mainly in the lvf. This suggests that the RH specialisation for non-verbal processes enhances promptness in eye guidance, especially with enough time to encode the target in working memory. With a word template, the first saccade was directed more often toward a lvf-target than a rvf-target. A picture template improved first saccade direction toward rvf-targets, while no template differences were found in the lvf. This indicates that only the RH can activate quickly an iconic representation of the target from its label. Overall, our results show that search initiation depends greatly on hemispheric specialisation.

◆ **Limitation of search strategies inside the dead zone of attention**

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The dead zone of attention (DZA) is exaggerated change blindness to objects near the center of interest (CI) [Utochkin, 2011, Visual Cognition, 19, 1063-1088]. Earlier, we have found that the manifestations of the DZA are reduced by informing observers about DZA [Stakina, Utochkin, 2012, Perception, 41, ECVP Supplement, 143]. In the present study, we tested whether it can be reduced by external cues drawing attention to a target region. Our change blindness experiment consisted of two stages. In the first stage, participants received 12 flickering images with changes in CI's. Once observers noticed those changes, CI's went the most attractive regions in the images. In the second stage, observers searched for peripheral changes either near, or far from CI's. Cues appeared during flicker intervals indicating the boundaries of a search region (those regions were significantly bigger than the sizes of changing details). It was found that the cues improved speed and accuracy of detecting both near and far changes as compared to our previous experiments. This demonstrates an economy provided by local search strategy. However, our manipulations didn't eliminate the DZA completely. It appears that the DZA is an enduring phenomenon that is more than just a search strategy. [The study was implemented within the Program of Fundamental Studies of the Higher School of Economics in 2013.]

◆ **Beta-band rTMS of the human attention network selectively modulates goal-driven, but not stimulus-driven search**

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Recent physiological observations have related mechanisms of top-down attention to oscillatory activity in the beta band. The aim of the present study was to test, by non-invasive neural perturbation of the human brain, if goal-driven (top-down) visual attention can be selectively modulated by stimulating nodes of the attention network with beta-band (20 Hz) rTMS. In 24 participants, we applied 20 Hz rTMS at the P4 or O2 location of the 10-20 coordinate system in two separate sessions. Online rTMS (10 pulses/450ms with 15s intervals) was interleaved with a goal-driven (feature-search) or a stimulus-driven (odd-one-out) search task. Active stimulation was replaced by sham stimulation in a subsequent offline phase. In a control session, we applied sham stimulation at an intermediate location. Performance was evaluated relative to a pre-session baseline and the control location. We found that beta-band rTMS at O2 and P4 modulated performance in the goal-driven, but not the stimulus-driven task. O2 stimulation led to a deterioration of goal-driven search during the online phase, but improved it beyond baseline during the subsequent offline phase. We conclude that it is possible to selectively modulate goal-driven versus stimulus-driven visual attention by applying beta-band rTMS to nodes of the human attention network.

◆ **Planning Search for Multiple Targets using the iPad**

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The Multi-Item Localisation (MILO) task is a useful tool for exploring both retrospective and prospective aspects of sequential search (Thornton & Horowitz, 2004 Perception & Psychophysics 66 38-50). A prominent feature of the MILO serial-reaction time function is a highly elevated response to T1 compared to T2 and subsequent targets. This "prospective gap" is thought to reflect forward planning. Here we present two new experiments that use the MILO iPad app to explore this prospective component. In Experiment 1, we randomly varied the sequence length between 2 and 8 items. Responses to both T1 and T2 systematically increased with set size. However, the T2 function had a shallower slope, presumably reflecting the benefit of forward planning. In Experiment 2, all displays contained 8 items, but observers were given a 0-6 second preview before responding. The T1-T2 gap reduced as the preview delay increased, but did not disappear even with a 6 second delay. Thus, forward planning cannot completely account for the gap. Together with our previous findings, these results suggest that the prospective gap is a combination of set-up time for registering a new visual layout, response preparation, and forward planning.

◆ **The time-course of visual masking effects on saccadic responses indicates that masking**

159 **interferes with reentrant processing**

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Object substitution masking (OSM) occurs when a briefly presented target in a search array is surrounded by small dots that remain visible after the target disappears. Here, we tested the widespread assumption that OSM selectively impairs reentrant processing. If OSM interferes selectively with reentrant processing, then the first feedforward sweep should be left relatively intact. Using a standard OSM paradigm in combination with a saccadic choice task, giving access to an early phase of visual processing (the fastest saccades occurring only 100 ms after target onset), we compared the masking time-course of OSM, noise backward masking, as well as a simple target contrast decrease. Consistently with a reentrant account, a significantly stronger masking effect was observed for slow (larger than median RT; average median RT = 177 ms) relatively to fast saccades in the OSM condition. Interestingly, the same result was observed using backward masking. In a follow-up experiment, where we assessed observer's visual awareness using single-trial visibility ratings, we demonstrated that these ultra-fast responses were actually linked to subsequent reported visibility. Taken together, these results suggest that OSM is indeed interfering specifically with reentrant processing during object recognition, which is consistent with traditional accounts of the OSM effect.

◆ **Eye movements change according to peripheral information**

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We use our central vision to distinct a target from distractors, and peripheral vision is important in planning and controlling saccadic eye movements, therefore central information analysis and selection of next saccadic targets can affect saccades, fixation duration and time needed to complete the visual search task [Liversedge and Findlay, 2000, Trends in Cognitive Sciences, 4(1), 6-14]. Methods are developing to train saccades, fixations and information processing via magnocellular flow [Kanonidou, 2011, Hippokratia, 15(2), 103-108; Sireteanu et al, 2008, Annals of the New York Academy of Sciences, 1145, 199-211]. In our research, we want to know how peripheral information influences eye movements and task efficiency during a visual search task. A participant has to find specific letters in the visual search task that differs in peripheral information – distractors have different colour and/or thickness than the target. From the results, peripheral vision helps to find the most efficient scanning algorithm to find the target using less saccades and fixations. As far as peripheral information changes, there are changes in number of fixations, fixation duration or both. When distractors and targets are the same in size and colour, more time is needed to scan each symbol and find the target.

◆ **Comparison of human and monkey eye-movement behavior under free viewing conditions**

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Macaque monkeys are the preferred model for investigation of visual attention, visual memory, and the oculomotor system. Yet, few experiments allow a direct comparison between monkeys and humans, and it is not known how well results generalize between species. Accordingly, we compared the viewing behavior of four macaque monkeys with that of 83 human observers freely viewing natural scenes, urban scenes and fractals. Image features showed virtually identical patterns of feature fixation correlations in both species (r^2=0.91), suggesting a similarity of stimulus-dependent attention mechanisms. Furthermore, human fixation locations, but not those of monkeys, were well predicted by locations marked as "interesting" by 35 independent observers (% of inter observer agreement: humans 94%, monkeys 67%). Conversely, a bottom-up salience model predicted fixation locations of monkeys better than those of humans (humans 64%, monkeys 76%). These findings show that bottom-up and higher level factors have a different influence on the guidance of viewing behavior in each species. We also observed that human viewing behavior predicted monkey behavior better than monkeys predicted human behavior. These findings suggest that monkeys and humans share stimulus-dependent attention mechanisms but that human viewing behavior is more strongly guided by stimulus-independent factors.

POSTERS : APPLICATIONS (ROBOTICS, INTERFACES AND DEVICES)

◆ **A neural social oddball signal lateralized to the right hemisphere**

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Visual evoked potential oddball paradigms are in general based on stimuli of relative simplicity. Here we investigated the neurophysiological correlates of complex social cognition using 3D human models as targets of attention. Challenging single trial classification of neural signals was attempted for detection of "social" oddball events. Non-animated stimulus target types were as follows: non-social control oddballs (rotating "balls"), gazing faces, rotating faces. Social target animations included rotating heads and head movement of 1 out of 4 avatars. We found a P300 signal for all stimulus types irrespective of their social complexity as assessed by repeated measures ANOVA. Symmetry analysis showed a specific right lateralization only for realistic social animations. These findings suggest a novel social cognition P300 component. The robustness of this social cognition signal was tested using single trial event classifiers. We obtained a significant balanced accuracy classification of around 79%, which is noteworthy due to social stimulus complexity. In sum, 3D stimuli representing complex ecological social animations elicit a right lateralized neurophysiological correlate of target detection. The fact that meaningful classifications of complex social events can be characterized even at the single trial level opens a potential application to brain computer interfaces in social cognition disorders.

◆ **Effects of mental workload during operation of a visual P300 brain-computer interface**

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The study aimed at identifying electrophysiological markers of fatigue and mental workload (high vs. low) and their effects on visual P300 brain-computer interface (BCI) performance. Twenty participants performed two concurrent tasks. During the BCI task, they had to focus attention on predefined characters of a 6x6-matrix, while rows and columns of the matrix flashed randomly. Mental workload was manipulated by dichotic listening tasks. Participants spelled with an average accuracy of 80% correctly selected letters in the low and 65% in the high workload conditions. A smaller P300 amplitude at Pz was observed in the high as compared to the low workload condition. Performance with the BCI was lower for the last as compared to the first run of both conditions. Increased activity in the alpha band was found at frontal, central and parietal electrode sites in the last run along with a higher subjective level of fatigue. Further, the P300 was smaller as compared to the first run. The high average performance under additional workload is promising for the use of BCIs in a home environment, where distraction is unavoidable. The identified electrophysiological markers could be used for automatic detection of fatigue or workload. [Supported by the European ICT-Program FP7-288566]

◆ **Combining event-related potentials and eye-tracking to assess the effect of attention on**
164 **cortical responses**

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Directing attention towards a stimulus enhances brain responses to that stimulus (e.g. Morgan et al, 1996, PNAS, 93, 4770–4774). Methods for investigating these effects usually involve instructing subjects to voluntarily direct attention towards a particular location, making them unsuitable for infants and other groups with poor communication. Here, we describe an approach based on fixation shifts (Atkinson et al, 1992, Perception, 21, 643), a method for behavioural assessment of attention in infants that does not depend on explicit instruction. We used event-related potentials (ERPs) to measure cortical activity preceding fixation shifts to peripheral targets. A remote eye-tracker was used to determine which target was fixated and the timing of the eye-movement towards it. With two identical targets presented at equivalent locations in left and right visual fields, adults showed an enhanced response at around 100 msec in occipital ERP channels contralateral to the subsequently fixated target, consistent with an effect of covert attention prior to the overt switch. Our initial results suggest this is a promising approach to investigating the effects of attention on cortical activity in infants and other populations who cannot follow instructions.

◆ **Toward Semantic Visual Attention Models**

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Visual information is very important in human perception of surrounding world. In the visual perception of the environment, specific parts of the observed scene are salient, i.e. more important than others. Visual attention is the ability of a visual system to detect these salient regions in the observed scene. In our work, we are focusing on detection of these salient regions in a complex scene using visual attention models. We utilize the visual attention model, which is based on local context suppression of multiple cues [Hu et al, 2005, Proceedings of IEEE ICME 2005, 346-349]. The model implement 3 attention cues: color, intensity and texture. We have extended this model with the semantic information about the scene by creating a new visual cue, the map of the occurrence of the important object. The importance of an object is usually very individual and task dependent. However some objects proved to be salient generally (faces, text..). Our approach can be utilized for the extraction of the salient regions in both task based (find object X in scene) and general situations. The information about salient regions in a scene can be further used in image compression, thumbnailing or retargeting.

◆ **Toward high performance, weakly invasive Brain Computer Interfaces using selective**
166 **visual attention**

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Brain–computer interfaces (BCIs) have been proposed as a solution for paralyzed persons to communicate and interact with their environment. However, the neural signals used for controlling such prostheses are often noisy and unreliable, resulting in low performance of real-world applications. Here we propose neural signatures of selective visual attention in epidural recordings as a fast, reliable, and high-performance control signal for BCIs. We recorded epidural field potentials with chronically implanted electrode arrays from two macaque monkeys engaged in a shape-tracking task. For single trials, we classified the direction of attention to one of two visual stimuli based on spectral amplitude, coherence, and phase difference. Classification performances reached up to 99.9%, and the information about attentional states could be transferred at rates exceeding 580 bits/min. Excellent classification of more than 97% correct was achieved using time windows as short as 200 ms. Classification performance changed dynamically over the trial and modulated with the task's varying demands for attention. Information about the direction of attention was contained in the Gamma-band, with the most informative feature being spectral amplitude. Together, these findings establish a novel paradigm for constructing brain prostheses and promise a major gain in performance and robustness for human BCIs.

◆ **EEG in Dual-Task Human-Machine Interaction: On the Feasibility of EEG based Support of Complex Human-Machine Interaction**

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Usually, humans can deal with multiple tasks simultaneously. We show here that even under high cognitive workload in dual task conditions, the human electroencephalogram contains patterns faithfully representing well-defined cognitive states. This finding allows the detection of these brain states while a human performs complex human-machine interactions, such as teleoperating a robotic system, thus presenting the possibility of improving operator performance. We present the results of two experiments recording the human electroencephalogram. Subjects performed a demanding senso-motor task (Brio labyrinth). During the performance of the senso-motor (labyrinth) task, two types of visual stimuli occurred. One type of stimulus could be ignored while the other, quite similar type, required a motor response (that interfered with the labyrinth task). We recorded the EEG by means of a 64 channel system with active electrodes (Brain Products) and found significant and characteristic event related potentials at parietal electrode sites even without averaging, i.e. on single events. These activities were more strongly expressed under dual task than under simple task conditions while response behavior was identical. Our results indicate that even under high workload it is possible to detect certain cognitive states in the human electroencephalogram possibly improving human-machine interaction.

◆ **Comparison of distributed source localization methods for EEG data**

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To improve the spatial resolution of EEG data distributed source localization can be used. Various methods have been proposed in the literature, but a key problem is that there is no standard procedure and metric how to evaluate and compare them. Moreover, along with simulations further evaluations on empirical data are required [Pizzagalli, 2007, in: Handbook of Psychophysiology, Cacioppo et al, Cambridge, Cambridge University Press]. Hence, we present a comparison of wMNE, sLORETA and dSPM reconstruction methods on movement intention data of 7 subjects. We compared the methods based on three criteria: (i) the distance of the nearest activation cluster to a reference region derived from literature, (ii) the number of found activation clusters and (iii) the difference in activation between the two conditions "movement" and "rest". The comparisons were performed on the average ERP and single trial data, respectively. For both levels the same qualitative results were obtained: wMNE reconstructions had the smallest distance and highest contrast, followed by sLORETA and dSPM. However, by using wMNE the number of found sources was much higher than for the other methods. The proposed approach provides a framework for a fair comparison between existing distributed source localization methods.

◆ **Looking at ERPs from Another Perspective: Polynomial Feature Analysis**

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Event-related potentials (ERPs) are classically studied measuring amplitude and latency characteristics of individual components. Such analysis is restricted to individual time points and largely ignores the temporal structure of the ERP. This motivates alternative pre-processing algorithms that might reveal new information about the signal encoded in the temporal relationships between neighbouring data points. In the current work, we fitted polynomials of orders one to four to ERPs (average and individual epochs) before analyzing the signal. Depending on other pre-processing methods (like subsampling and filtering), a low order polynomial should be able to capture the ERP's shape and reduce noise in single-trials. The polynomials were fitted on local segments over the whole epoch and the subsequent analysis was performed with the resulting coefficients instead of the amplitude values. For evaluation we used data from an oddball task evoking a broad P300 component (five subjects, two sessions each). The descriptive quality of the coefficients was derived from the performance of a support-vector machine classifying ERPs labelled as 'standard' and 'target', respectively. The corresponding ERP topographies (both, average and single epochs) strengthen the notion that analysis of polynomial features provides a tool for exploration of new relationships in ERP data.

◆ **Identifying Perceptual Features of Procedural Textures**

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Identifying perceptual texture features is important for texture generation, browsing and retrieval. This work focused on investigating perceptual features of procedural textures. We generated 450 samples using 23 generation methods. We designed two psychophysical experiments: free grouping and rating. First, twenty observers were asked to group the 450 samples, from which a similarity matrix of 23 methods was created. Hierarchical cluster analysis (HCA) was applied to the matrix and these methods were clustered into 10 classes. Second, observers rated each sample six times in the 12 texture description dimensions proposed by [Rao A.R and Lohse G.,1996, Vision Research, 36(11), 1649-1669] using 9-point Likert scales. We trained a support vector machine model for prediction based on the HCA results with the 12-dimensional features. For all texture generation methods, the accuracy for predicting a given sample belonging to a certain class was 59.22% for the leave-one-out test. However, when we selected five near-regular texture generation methods based on the rating data, the prediction accuracy was raised to 91%. These results indicated that the 12 perceptual features could be used to discriminate near-regular texture classes as human perceived; however, they are not good enough for discriminating random textures classes. [NSFC Project No. 61271405]

◆ **Cotton Grading: Can Image Features Predict Human's Visual Judgment?**

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Although optical devices have been invented for grading cottons, the output is not well coincident with human's visual judgment. Trained workers are still widely used to manually inspect and grade cottons; the process is inefficient and subjective. We proposed an economic method that analyzed digital images of cottons and used machine learning techniques to simulate human's visual perception for cotton grading. Since "Color", "leaf" and "preparation" are three major factors used by human graders, we extracted following computational properties from cotton images to represent these factors: the mean and variance of L*, b*, a* colour components for "color"; the percentage area, average size, number and scatter of trashes for "leaf"; the Gray Level Co-occurrence Matrices for "preparation". A 21 dimensional feature was generated from one single image. After performing Principal Component Analysis, we used these features to train a k-Nearest Neighbor classifier. We tested our method using standard references (7 grades) and real samples (4 grades). 126 standard references (18 in each grade) were used as the training set. The grading accuracy is 90.5% when using 42 standard references (6 in each grade) as the validation set, and is 87.5% when using 15 real samples as the testing set. [NSFC Project No. 61271405]

◆ **cVIS - A Software System for Analyzing Visual Perception**

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We are developing the cVIS framework to analyze perceptual and cognitive processes of users who are working with visualizations. The framework supports the analysis with three modules: eye tracking data visualization and analysis, semantic models and a cognitive simulation. We will present results of ongoing work on the development of new visualization techniques for eye tracking data. For example, we are using the parallel scan-path visualization technique [Raschke et al., 2012, Proceedings of the 2012 Symposium on Eye-Tracking Research and Applications, 165-168] besides heat maps and scan path visualizations to analyze the influence of different visualization parameters such as graphical layout, visual data density, line thickness, colors or textures on the visual perception. Today the development of data visualizations is mostly driven by a technical perspective. To support a user centered visualization design process we will show different approaches which are using a semantic annotation of areas on the stimulus for a better understanding of higher cognitive processes such as visual reasoning. Results from eye tracking data analysis and semantic knowledge models of visualizations are used to develop an ACT-R based cognition simulation framework.

◆ **Effective LIC Parameter Selection Based on Human Perception and Conditional Entropy**

173 Y Sun, J Dong, L Qi, S Xin, S Wang (Department of Computer Science and Technology, Ocean University of China, China; e-mail: dongjunyu@ouc.edu.cn)

Line integral convolution (LIC) is a widely used algorithm that generates textures for visualizing of flow field. However, the algorithm parameters are usually set experientially, which results in visual effects that may not be perceptually optimized. We proposed a method that finds parameter values coinciding with human's visual perception. A computational perception model [Daniel Pineo and Colin Ware, 2012, Visualization and Computer Graphics, 18(2), 309-320] was used on the flow field generated by LIC to produce an intermediate field, which simulated perceived flow direction. The similarity between this intermediate field and the actual vector field was measured using conditional entropy. Four different flow fields were chosen for test. We sampled ten different LIC parameter values to produce texture stimuli. In the psychophysical experiment, observers rated the similarity of the LIC textures and the corresponding vector field. The results showed that conditional entropy correlated well with human's ratings, and our proposed method can be used as a perceptual guidance for LIC parameter selection. [NSFC Project No. 61271405]

◆ **Towards a quantitative metric of facial scarring by analyzing qualitative descriptions**

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The surgical correction of cleft lip in infancy leaves a distinctive pattern of scarring on the upper lip. In previous studies we have attempted to characterize these scars using machine vision algorithms and consensus coding by lay observers [Simmons et al, Perception 40, ECVP Supplement, 155]. In this study we have augmented these data using a qualitative approach. Thirteen lay observers (i.e. no previous interest in surgery or facial scarring) examined 87 images of the top lips of children who had previously had corrective surgery. They were asked to describe the images in their own words. These descriptions were recorded and then analyzed to identify the key perceptual dimensions of scarring. The dimensions identified in the descriptions were: colour, shape, texture, visibility, severity and empathy. Colour was by far the most frequently-used descriptor, with over 600 descriptions in total; shape, texture and visibility were each used 300-400 times. By using intensity data also supplied by participants it was possible to rank the scars on dimensions like redness, whiteness, smoothness and indentedness. These dimensions can therefore form the basis for a quantitative characterization of facial scars. This technique has implications for characterization of visual appearance in many other applications.

◆ **Computational proto-object detection in 3D data**

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For humans as well as for machines, object detection is an essential task to understand the world and interact with it. The situated vision theory of Pylyshyn (Pylyshyn, 2001, Cognition 80, 127-158) states that in human vision, the detection of visual objects preceeds the categorization and investigation of their properties. This is in contrast to the standard approach in computer vision that usually learns object categories and applies the resulting classifiers to images. In this work, we present a computational approach that follows the idea of Pylyshyn and detects proto-objects without prior knowledge about categories or properties of objects. The detection is based on a visual attention system that detects salient blobs which are improved by iterative segmentation steps. As input device, we use a depth camera that provides color as well as depth information and is used to create a 3D representation of the scene. Detected proto-objects are projected into this 3D scene map and incrementally updated when data from new viewpoints is available. The system is able to find unknown objects and to create 3D object models without prior knowledge in real-world scenarios.

◆ **The advantages of coarse-to-fine processing – a Computer Vision Approach**

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The idea that the visual system can work more efficiently if it uses a "coarse-to-fine" processing strategy is a popular one. Here we used extensive testing of object and scene recognition with a biologically-inspired computer vision system developed by SpikeNet Technology SARL (http://www.spikenet-technology.com) to demonstrate that these advantages are very real. The standard SpikeNet recognition process typically uses image patches roughly 30 pixels across. This gives good selectivity combined with reasonably high robustness to image transformations such as rotation, size changes, and 2- and

3D transformations. Using smaller patch sizes allows the system to detect a given target over a wider range of transformations, but with less selectivity. Thus 30px models achieve about 10° tolerance to rotations, where the 18px ones can go up to 20°. However, if we combine an initial processing phase using a relatively coarse image patch (e.g. 18 pixels across), coupled with a second processing phase using image patches 50% wider, recognition is not only more robust, but also a lot more efficient. This translates into using fewer neurons than would be needed with the standard approach, and also means that the software implementation runs 4-5 faster on standard computer hardware than the original algorithm.

◆ **Hierarchical feature representation reduces the Müller-Lyer effect**

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Deep neural networks inspired by visual cortex demonstrate superior pattern recognition compared to their shallow counterparts. These artificial neural networks (ANNs) with hierarchical feature representation also provide a new method for investigating visual illusions. Recently, a state-of-the-art computational model of biological object recognition, HMAX, was found to exhibit a bias in line length of when shown Müller-Lyer stimuli. The Müller-Lyer Illusion (MLI) is a visual illusion wherein a line appears elongated with arrowtails and contracted with arrowheads. The combined and separate contributions of training stimuli and elements of neural computation can be explored in ANNs to investigate the possible causes of an illusory effect. In this study we investigate whether the MLI occurs because of feature representation built from "simple" and "complex" cells or whether using an SVM as the decision-making module drives the effect. We ran dual category line length discrimination experiments in both the full HMAX model (including an SVM stage) and an SVM-only model. Unexpectedly, the SVM demonstrated an even larger misclassification of line length than shown by HMAX. These results indicate that a simple-complex neural architecture is not necessary to simulate the illusion but rather suggests that filtering and max pooling operations reduce the Müller-Lyer effect.

◆ **Sensorimotor integration using an information gain strategy in application to object recognition tasks**

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Humans can recognize 3D objects robustly and accurately. There is evidence that in natural settings this competence involves not only sensory processing but also motor components. This is not only true for the recognition act itself but also for the representation. However, while we have powerful models for pure sensory processing (hierarchical feed-forward networks), models for a sensorimotor approach to object recognition are rare, and do often address only part of the problems. In particular, it is not yet clear what the specific relations between motor states and sensor information are, and how they enter into the underlying representation. Here we developed and implemented a probabilistic model for object recognition which combines motor states and bottom-up processes of feature extraction in an integrated sensorimotor architecture. The top-down process computing the next movement of the robot is modeled by an information gain strategy which uses a sensorimotor knowledge base to obtain the most informative motor action. In a training phase the knowledge base is learned from real data to obtain the sensorimotor representation. We show how the integration of motor actions effects task performance in comparison to the modeling approach which only takes sensor information into account.

◆ **The software model of the Mirakyan's "Perceptron"**

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The work is focused on the computer model of the coding device (homothetic to "Perceptron" in the sense of implementation of theoretical principles), which had been developed by Russian psychologist Prof. A.I. Mirakyan on the basis of Transcendental Psychology approach [Artemenkov and Harris, 2005, Journal of Integrative Neuroscience, 4 (4), 523–536] about 25 years ago. The model represents a unified generative process of form code creation of images shown on the receptive field layer and implements dynamic formation of symmetric bi-united relations and their memorization within discrete logical spatial-temporal system. The output layers include a reduced number of active elements and provides for spontaneous selection of separate objects, separation of the objects in the frame without preliminary description of objects' features and certain stability of identification in the presence of

changing surroundings. Produced program was developed using NI LabView 2010 and simulates the behavior of Mirakyan's Perceptron when images with different size and form are applied to the receptive field. The results received for receptive field 64x64 elements are consistent with theoretical predictions. The model is possible to use for classification and evaluation of the symmetry properties of various geometric objects in robotic or other artificial visual systems.

◆ 180 **High-reality space composition using stably-positioned imaging and acoustic wave field synthesis**

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We propose a natural communication concept produced by high-reality space composition made by using the high fidelity position representation induced by a stably-positioned imaging technology and acoustic wave field synthesis technology. It provides natural and comfortable communication by reproducing the distance and position of an image and sound without inconsistency. Stably-positioned imaging technology is supported by two technologies. One provides a natural sense of distance and positional relations by considering the observer's perspective. The other is multi-view point images applying the parallax perception from our depth-fused 3D (DFD) visual perception [1]. We have also made it possible to record and reproduce an acoustic space in real time by applying our new algorithm [2] for physically reconstructing acoustic waves to large scale microphone and loudspeaker arrays. We used these technologies to develop a high-reality space composition system and used it to obtain results for perceived relationships between image and sound. These results will lead to achieving a synergistic effect of image and sound that can be applied to high-reality communication systems. [1] H. Takada et al, 2006, Perception, 29 ECVP, 31. [2] S. Koyama et al., 2013, IEEE Trans. Audio, Speech, Lang., Process., 21(4), 685-696.

◆ 181 **Assessment of fusional reserves with interactive software: Dependence of results on left-right image separation method**

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Fusional reserves were measured in 50 young adults using our original computer-aided method described earlier (Rozhkova and Vasiljeva, 2010 Human Physiology 36(3) 364-366) but somewhat modified. In a new series of measurements, the stimuli were generated on the 3D display making it possible to employ both color and polarization techniques of image separation in similar conditions and to assess the influence of separation method. Correspondingly, in one series of measurements, left and right images were presented in anaglyphic form; in another series, left and right images were presented on differently polarized rows of pixels. The results obtained with color separation techniques were similar to the results of our previous measurements using this method with another display. However, the results obtained with polarization techniques appeared to be significantly better as concerned critical values and reproducibility. For instance, in the histogram of convergent (base-out) fusional reserves obtained with polarization method, the main peak was found at 30-35deg whereas, with color method, the main peak corresponded to 15-20deg. This difference suggests that a significant difference in color between left and right images might exert essential negative effect on the functioning of fusion mechanisms. Supported by the Program of DNIT Russ Acad Sci.

◆ **Component Extraction and Motion Integration Test (CEMIT)**

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We have developed an App capable of measuring how well observers can extract components from a moving plaid and then reintegrate them, using a novel direction discrimination task (Bowns, 2012, Perception, (42), 98). Here we describe an App version of the test "CEMIT" that will be available for download from Apple AppStore for the iPhone, iPod touch, and iPad. An extended version of the test will also be available for research groups. We compare results obtained under strict laboratory conditions with those obtained from CEMIT. We also provide an example of how performance can reveal a deficit, and how performance changes dramatically at the limits. CEMIT will be an important resource for many researchers and clinicians where cortical visual problems have been implicated, e.g. dyslexia, Alzheimer's disease, dementia, autism; or for screening purposes where visual information plays a very important role, e.g. drivers, pilots, or air traffic controllers. This test provides individual information at the neuronal level that no eye test or current scanning technique could access.

◆ **Rapid and precise assessment of the temporal contrast sensitivity function on an iPad**

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The natural world can be highly dynamic, and the temporal contrast sensitivity function (tCSF) therefore describes a fundamental component of real-world vision. Its high-frequency cutoff corresponds to critical flicker fusion, and changes in the tCSF can be clinically diagnostic for a variety of neurodegenerative eye diseases such as glaucoma or AMD. We have implemented a rapid and precise test of the tCSF on the iPad, based on the qCSF family of adaptive behavioural measurements [Lesmes et al, JoV 2010]; the tCSF is described by only four parameters and stimulus selection maximizes the expected information gain for each trial, reducing the number of required trials for full tCSF characterization to only 15-30 in a 10AFC task. Because of the known issues with temporal properties of digital displays [Elze, J Neurosci Methods, 2011], we carefully evaluated the iPad display with an Optical Transient Recorder. We found strong nonlinear effects that depend on contrast level and frequency, and that need to be compensated for during stimulus selection and display. Combined with previous work on precise assessment of the spatial CSF [Dorr et al, ECVP 2012], our test battery on the iPad platform now allows full characterization of visual sensitivity outside the laboratory.

THURSDAY

SYMPOSIUM : ARE EYE MOVEMENTS OPTIMAL?

- **Timing of saccadic eye movements during demanding visual tasks**

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Decisions about directing gaze are, explicitly or implicitly, decisions about managing time. Given that most visual discriminations are completed within the duration of a typical fixation, the best strategy should be to aim for highest possible saccade rates in an effort to fixate as many locations as possible in the available time. To examine this possibility, we studied saccadic timing in two visual tasks, a scanning task that required localization judgments, and a visual search task that required search for multiple targets. Timing patterns of saccades depended on a host of factors including: the quality of available visual information (both foveal and extrafoveal), the functional role of the saccade (exploratory vs. targeting), expectations about the time needed to make visual decisions, and the ordinal position of the saccade in the sequence. These results show that saccadic timing is not set to uniformly high rates by default. Timing is modulated according to available visual information, momentary goals, memory, and expectations. These factors operate cooperatively to ensure efficient management of time and processing resources during the performance of visual tasks.

- **Human eye movements are optimal for face recognition**

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When identifying faces humans initially look towards the eyes. Unknown is whether this behavior is solely a by-product of socially important eye movement behavior (i.e., good eye contact) and the extraction of information about gaze direction, or whether the saccades have functional importance in basic perceptual tasks. Here, we propose that gaze behavior while determining a person's identity, emotional state, or gender can be explained as an adaptive brain strategy to learn eye movement plans that optimize performance in these evolutionarily important perceptual tasks. We show that humans move their eyes to locations that maximize perceptual performance determining the identity, gender, and emotional state of a face, with fixations away from these preferred points resulting in significant degradation in perceptual performance. These optimal fixation points, which vary moderately across tasks, are correctly predicted by a Bayesian ideal observer that integrates information optimally across the face but is constrained by the decrease in resolution and sensitivity from the fovea towards the visual periphery (foveated ideal observer). Neither a model that disregards the foveated nature of the visual system and makes fixations on the local region with maximal information, nor a model that makes center-of-gravity fixations correctly predict human eye movements. These results suggest that the human visual system optimizes face recognition performance through guidance of eye movements.

- **Optimal and non-optimal fixation selection in visual search**

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Under some circumstances humans are very efficient at fixation search. For example, in practiced observers, both the search time and the statistics of fixation locations and saccades have many characteristics of an ideal searcher, when the search target is known and the background is either a uniform field or a field of white or 1/f noise. However, there are circumstances where humans do not make optimal eye movements, and there are many more situations where one would not expect them to. I will discuss at least two cases. One case is at the start of the search trial where the observer may prepare for an eye movement, or eye movements, before the trial starts. The second case is search in complex displays, even with a single known target. Optimal fixation selection depends on the observer having an estimate of the detectability of the target at different locations across the visual field. When the background is complicated (highly non-stationary) the computational demands of estimating detectability can be very high. Under such circumstances humans are almost certain to adopt simpler (non-optimal) fixation selection strategies. [Najemnik and Geisler, 2005, Nature 434, 387-391; 2009, Vision Research, 49, 1286-1294; 2008, Journal of Vision, 8, 1-14]

- **Sub-optimal eye movement strategies in simple visual and visuo-motor tasks**
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We test whether human observers choose optimal eye movement strategies in three simple visual tasks where it is possible to calculate the optimal eye movement strategy maximizing. First we show that human observers do not minimize the expected number of saccades in planning saccades in a simple visual search task composed of only three tokens (Morvan & Maloney, 2012). Second, using a simple decision task, we directly evaluated human ability to anticipate their own retinal inhomogeneity. Observers exhibited large, patterned failures in their choices (Zhang, Morvan & Maloney, 2010). Last, we examined an eye-hand coordination task where optimal visual search and hand movement strategies were inter-related. Using Bayesian decision theory we derived the sequence of interrelated eye and hand movements that would maximize expected gain and we predicted how hand movements should change as the eye gathered further information about target location. We found that most observers failed to adopt the optimal eye movement strategy but that – given their choice of eye movement strategy – their choice of hand movement strategy came close to optimizing expected gain. We find little indication that the eye movement strategies adopted by human observers optimize their expected gain.

- **Dynamic integration of salience and value information for saccadic eye movements**
A Schütz (Department of Psychology, Justus-Liebig-University Giessen, Germany; e-mail: alexander.c.schuetz@psychol.uni-giessen.de)

Humans shift their gaze to a new location several times per second. Fixation behavior is influenced by the low-level salience of the visual stimulus, such as luminance and color, but also by high-level task demands and prior knowledge. Under natural conditions, different sources of information might conflict with each other and have to be combined. In our paradigm [Schütz et al, 2012, PNAS, 109(19), 7547-7552], we traded off visual salience against expected value. To manipulate salience, we varied the relative luminance contrast of two adjacent regions. To manipulate value, we varied the amount of reward and penalty. In a salience baseline condition, we instructed subjects to make saccades to the regions, without reward or penalty. In the easy value condition, subjects won money for landing on one region. In the difficult value condition, subjects additionally lost money for landing on the other region. We show that salience and value information influenced the saccadic end point within the regions, but with different time courses. Short-latency saccades were determined by salience, but value information was taken into account for long-latency saccades. We present a model that describes these data by dynamically weighting and integrating detailed topographic maps of visual salience and value.

- **Saccadic efficiency in visual search for multiple targets**
P Verghese (Smith-Kettlewell Eye Research Institute, CA, United States; e-mail: preeti@ski.org)

We investigated saccadic targeting when observers actively searched a display to find an unknown number of targets. Search time was limited, so saccades needed to be efficient to maximize the information gained. As there was insufficient time to examine all potential target locations, selecting uncertain locations was much more informative than selecting likely target locations; saccades to uncertain locations could resolve whether a target was present, whereas a saccade to likely target locations provided little additional information. Observers actively searched a display with six potential target locations embedded in noise. At the end of a brief display (1150 ms), observers reported all locations with a target. Each location had an independent probability of having a target, so the number of targets varied from 0 to 6 from trial to trial. Contrary to the prediction for maximizing information, observers made saccades to likely target locations, rather than to uncertain locations. Full feedback after each trial did not improve saccadic efficiency. We therefore examined whether immediate feedback following each saccade improved performance. Modest practice with immediate feedback resulted in significant improvements in saccadic efficiency, suggesting that observers were able to overcome partially a natural tendency to saccade to likely target locations.

TALKS : CONTOURS AND CROWDING

- **Modal and amodal thin-fat Kanizsa shape discrimination with classification images in stereo**

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Purpose. We investigated thin-fat Kanizsa shape discrimination (Ringach and Shapley, 1996), using classification images (CIs) in stereo. We asked: (1) Are modal and amodal shape discriminations equally good? (2) To what extent does contour completion occur after binocular fusion? Method. The thin or fat Kanizsa shape was either in front of the inducers in depth (modal) or, when the left- and right-eye images were switched, behind four holes (amodal). Noise was added either to the inducer plane or, as control, to the Kanizsa shape plane. The luminance of the background and the contrast of the noise were fixed. The luminance of the inducers was adjusted so that thin-fat discrimination was 70.7% correct. For each condition 10,000 trials were run. Seven subjects participated. Results and conclusions. (1) The inducer contrast threshold was higher for amodal (0.31) than for modal (0.26) discrimination, $p = 0.001$, implying that their mechanisms were unlikely to be identical. (2) The CIs showed two vertical bands at the locations of the vertical contours of the Kanizsa shape, with an offset identical to the binocular disparity. This result suggests that contour completion took place before binocular fusion. The single bands in the control CIs further support this suggestion.

- **The contribution of local contour features to global shape processing**

I Fründ, J H Elder (Center for Vision Research, York University, Toronto, ON, Canada; e-mail: mail@ingofruend.net)

How do local properties of bounding contours contribute to visual processing of shapes? We address this question using maximum entropy probability models on the space of simple (non-intersecting), closed contours. We approximated 391 animal shapes by equilateral polygons and analyzed the statistics of the polygons' turning angles. We tested four different models: an unconstrained model, that samples the space of simple, closed contours uniformly, and models that successively constrained the expected angular variance of a shape, the angular kurtosis and the circular correlation between neighboring angles to be equal to the animal shapes. Observers were to select the "more likely natural" one of pairs of shape fragments that differed with respect to one constrained feature. Performance was close to ideal when the fragment pairs differed in circular variance. Performance was at chance when the informative feature was circular kurtosis or circular correlation between neighboring angles. This suggests that observers judge naturalness of shape fragments only partly based on local contour information. We believe that this information is complemented by more global shape features.

- **Filling-in and contour adaptation**

S Anstis (Psychology, UCSD, CA, United States; e-mail: sanstis@ucsd.edu)

Contour adaptation (CA) is a novel aftereffect. Following adaptation to a thin, flickering outline circle, the whole of a congruent low-contrast disk disappears from view for several seconds. Thus CA can temporarily erase edges, allowing the background grey to fill-in the area of the disk. This suggests that luminance information is stored in edges and contours and propagates inwards from them. CA erases only luminance edges, not colored edges, and it shows no interocular transfer, so it probably arises early in the M pathways. It halves the perceived contrast of medium-contrast test disks, and pushes low-contrast test disks below threshold so that they disappear entirely. A peripherally viewed grey square superimposed on low-contrast horizontal stripes is clearly visible. But adaptation to a thin outline flickering square makes the grey test square become invisible, so now the stripes appear to extend continuously across the position of the square. This CA-induced “filling-in” models the filling-in of the natural blind spot, and of acquired scotomata in glaucoma or Stargardt’s disease. CA may help to clarify whether such filling-in is passive (Dennett 1991) or active (Churchland & Ramachandran 1995).

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- **A new model for border-ownership computation reflecting global configuration and consistency of surface properties**
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We developed a model (Kogo et al, 2010, Psychological Review, 117(2), 406-439) that reproduces figure-ground organization by implementing global interactions of border-ownership (BOWN) signals. The algorithm works in favor of convex shapes, corresponding to human perception. However, in certain conditions, this convexity preference is reduced. For example, if a convex region is on top of another surface and has the same color/texture as the background, it is often perceived as a hole. The preference of convex regions in repetitive columnar configurations is also reduced if the concave regions have inconsistent colors (Peterson and Salvagio, 2008, Journal of Vision, 8(16):4, 1-13). These data suggest that consistency of surface properties plays a key role in figure-ground organization. Importantly, Zhou et al. (2000, Journal of Neuroscience, 20(17), 6594-6611) showed that roughly half of BOWN sensitive neurons in V2/V4 were also sensitive to contrast polarity. We developed a new algorithm so that only when interacting BOWN signals are consistent in both owner side and contrast, their signals are enhanced. With this, we are able to reproduce the reversal of the convexity preference. The general implications of this new approach will also be discussed.

- **Crowding and grouping: how much time is needed to process good Gestalt?**
  M Manassi, M Herzog (Laboratory of Psychophysics, École Polytechnique Fédérale de Lausanne, Switzerland; e-mail: mauro.manassi@epfl.ch)

In crowding, perception of a target is deteriorated by flanking elements. Crowding is usually explained by pooling models where target and flanker signals are averaged. We show here that crowding is rather determined by grouping and good Gestalt. We determined offset discrimination thresholds for verniers with different flanker configurations. When the vernier was flanked by two vertical lines, thresholds increased. Surprisingly, when the two lines were part of two cubes, thresholds decreased. This finding cannot be explained by pooling models, which predict stronger crowding for the cubes because more irrelevant lines are pooled. We explain our results in terms of grouping. When the target groups with the flankers, performance deteriorates (two-lines condition). When the flankers are part of a good Gestalt, the target ungroups from the flankers and performance improves (cube condition). For short durations (20-80 ms), thresholds were similarly high for the lines and the cubes conditions. For longer stimulus durations (160, 320 and 640 ms), thresholds stayed high for the two-lines conditions but decreased for the cubes condition. Our results show that Good Gestalt in crowding emerges "slowly" within 160 ms.

- **Drawings of the visual periphery reveal appearance changes in crowding**
  B Sayim, J Wagemans (Laboratory of Experimental Psychology, University of Leuven (KU Leuven), Belgium; e-mail: bilge.sayim@ppw.kuleuven.be)

In peripheral vision, objects that are easily discriminated in isolation are not discernible when flanked by similar close-by objects, a phenomenon known as crowding. Here, we investigated the appearance of crowded stimuli by letting observers draw stimuli presented in the periphery. Targets consisted of a letter, a letter-like item, or a scrambled letter and were presented with or without flankers of different complexity. Targets were presented in the right visual field at eccentricities of 6 or 12 degrees. Observers were asked to draw the stimuli - target and flankers - as accurately as possible. Eye tracking ensured that stimuli were only presented when observers fixated on a central fixation dot. When not fixating, stimuli were masked. We evaluated the resulting drawings and found evidence for strong changes of appearance when the stimuli were crowded. For example, several characteristics of crowding, such as position shifts of elements or target-flanker confusions, were observed. Importantly, frequent distortions, omissions, and duplications of elements indicate that crowding involves a broad spectrum of "perceptual errors" that are not revealed in standard crowding paradigms. We propose that drawings are a useful tool for investigating crowding.

- **Natural-amplitude saccades uncrowd targets in the parafovea**
  L Walker, S Ghahghaei (Smith-Kettlewell Eye Research Institute, CA, United States; e-mail: laura@ski.org)

Crowding is typically studied during fixation with covert attention to the target, and demonstrates a radial-tangential anisotropy (Toet & Levi, 1992, Vision Research 32, 1349-1357). During natural vision, eye movements necessarily alter the relative relationship of flankers to targets. Interestingly, flankers will

rotate from the radial to tangential configuration in the parafovea for 4deg saccades – coincident with the peak of the natural saccade amplitude distribution. Here we examine whether saccades indeed impact crowding of unattended parafoveal targets. In a primary task, participants made three, timed saccades between four fixation targets. During the second and third fixations, an oriented gabor target appeared off the path in the upper or lower parafovea, flanked by plaid crowders. In a secondary task, participants were asked to report the orientation of this target. Spatial frequency and flanker-target distance was manipulated to measure crowding strength. Trials with inaccurate/untimely saccades were discarded. As attention was not directed toward the target, we find an overall increase in crowding. When the relative position of flankers was manipulated to preserve radial/tangential configurations despite eye movements, the hallmark anisotropy was preserved. When eye movements served to rotate the flankers, the two fixations were cumulative and crowding factors fell between the radial and tangential bounds.

- **Spatial frequency sensitivity does not explain the reduction in perceived numerosity in the peripheral visual field.**
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When human observers are asked to judge the number of elements in a peripheral crowd, their estimates are reduced compared to foveal presentation [Valsecchi et al, 2012, Perception, 41 ECVP Supplement, 128]. In the present contribution we investigate whether this effect is explained by the differential spatial frequency sensitivity, in the light of the proposal that a ratio of high to low spatial frequency channel output is used to estimate numerosity [Dakin et al. 2011, PNAS, 108]. We constructed filtered images of our dot arrays devised so as to produce comparable channel outputs centrally and peripherally. First we decomposed our arrays into 8 images with power concentrated at increasing spatial frequencies. Subsequently we measured peripheral and foveal detection thresholds for each component image and recombined them after weighting each image by its detection threshold. When judging the numerosity of such filtered images our observers still exhibited the reduction (around 10%) in peripheral numerosity we observed with the original images, excluding a simple explanation in terms of spatial frequency sensitivity. We suggest numerosity in the peripheral visual field is computed from channels tuned to a lower spatial frequency rather than from channels with the same spatial frequency tuning but lower sensitivity.

TALKS : MULTISENSORY PERCEPTION AND ACTION

- **Differential modulation of visually evoked postural responses by real and virtual foreground objects.**
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Externally generated visual signals that are consistent with self-motion, cause corresponding visually evoked postural responses (VEPR). These VEPR are not simple responses to optokinetic stimulation, but are modulated by the configuration of the environment. We measured VEPR in a virtual environment where the visual background moved in either lateral or anterior-posterior direction. We show that: 1) VEPR for lateral visual motion are modulated by the presence of foreground objects that can be haptic, visual and auditory; 2) real objects and their virtual reality equivalents have different effects on VEPR; 3) VEPR for anterior-posterior motion are not modulated by the presence or reality of reference signals in the foreground. We conclude that automatic postural responses for laterally moving visual stimuli are strongly influenced by the configuration and interpretation of the environment and draw on multisensory representations. Different postural responses were observed for real and virtual visual reference objects. On the basis that VEPR in high fidelity virtual environments should mimic those seen in real situations we propose to use the observed effect as a robust objective test for presence and fidelity in VR.

- **The effect of exploration mode on visuo-haptic slant perception**
  M Plaisier, L C van Dam, C Glowania, M Ernst (Cognitive Neurosciences, Bielefeld University, Germany; e-mail: myrtheplaisier@gmail.com)

Visual and haptic information can be integrated in a statistically optimal fashion, however, for slant perception reports exist of suboptimal integration [Rosas et al, 2005, J. Opt. Soc. Am. A, 22(5), 801-809]. It was hypothesised that this may be related to the exploration mode, which was not equal. Therefore we

investigate the role of exploration mode in visuo-haptic slant integration Participants looked onto a 3D rendered surface through shutter glasses, while haptic information was displayed using two PHANToM force-feedback devices. In the "serial" condition participants moved the index finger to explore the surface. Visually, the surface was visible through a small circular aperture around the finger. In the "parallel" condition, participants placed the index and middle finger simultaneously on the surface and held them stationary. In this case a circular aperture was displayed around each finger. The visual slant percept was more precise in the parallel condition, whereas haptic slant was more precise in the serial condition. In contrast to the Rosas et al. study, the exploration for both modalities was the same within conditions. Our results suggest that as long as the exploration mode is the same for both modalities, there is statistically optimal integration regardless of exploration mode.

- **Cuteanous texture information influences kinaesthetic movement direction**
  W Bergmann Tiest, A Kappers (Faculty of Human Movement Sciences, VU University Amsterdam, Netherlands; e-mail: w.m.bergmanntiest@vu.nl)

In haptics, like in vision, a moving grating perceived through an aperture is interpreted as moving in the direction perpendicular to the orientation of the stripes, regardless of the actual movement direction [Bicchi et al, 2008, Brain Research Bulletin, 75, 737—741; Pei et al, 2008, PNAS, 105(23), 8130—8135]. This was shown in passive perception, with the hand stationary and the grating moving. Our question was, whether this is also the case with the hand moving over a stationary grating. In that situation, two movement direction cues are available that might contain conflicting information: a kinaesthetic cue from the limbs and joints, and a cutaneous cue from the finger touching the grating. We measured the relative contribution of these two cues in an experiment. Blindfolded subjects were asked to move their finger parallel to either the frontoparallel or the midsaggital plane over a grating that was oriented either +45° or -45° from the instructed movement direction. A significant difference in actual movement direction ($p = 0.0099$) was found for the radial movement, depending on the orientation of the grating. On average, 4±1 (mean±SE) percent of the movement direction is based on cutaneous input, and the rest on kinaesthetic input. [This work has been partially supported by the European Commission with the Collaborative Project no. 248587, "THE Hand Embodied", within the FP7-ICT-2009-4-2-1 program "Cognitive Systems and Robotics"]

- **Synthesis of vibrotactile frequencies**
  S Kuroki, J Watanabe, S Nishida (Human Information Science Laboratory, NTT Communication Science Laboratories, Japan; e-mail: kuroki.shinobu@lab.ntt.co.jp)

Since combination of signals from trichromatic cone photoreceptors forms visible color in human vision, a wide range of colors can be artificially reproduced from a small number of primary colors. Conceptually similar to color vision, vibrotactile signals are detected by a few broadband receptors, each sensitive to low- and high-frequency vibrations. It is known that the activation of each mechanoreceptor can carry information about vibration frequency, but the relative activity of the two mechanoreceptors could be also a useful code of frequency as in color vision. If so, a range of perceived frequency might be artificially reproduced only by a few frequencies, each activating separate channel. To test this possibility, we simultaneously presented 30 Hz and 240Hz vibrations to different fingers of the participants, and asked them to judge whether the perceived frequency of the synthesis pair was lower or higher than that of 30, 42, 60, 85, 120, 170, or 240 Hz vibrations presented to the same two fingers. The results indicated that the apparent frequency of synthesis pair was in the middle of the two presented frequencies, with the position being shifted according to an intensity ratio of the two frequencies. Our result demonstrates synthesis of vibrotactile frequencies.

- **EEG effective connectivity neurofeedback training increases sound-induced visual illusion**
K Yun, S Shimojo (Computation and Neural Systems, California Institute of Technology, CA, United States; e-mail: yunks@caltech.edu)

EEG neurofeedback has been applied to modulate specific frequency amplitude in certain regions of the brain. Conventional EEG neurofeedback training has been targeting specific frequency range to modulate its amplitude. The purpose of the study was to test whether we can modulate effective connectivity (i.e., direction of information flow using partial directed coherence) between brain regions using neurofeedback training. We found that effective connectivity from auditory to visual cortex (A->V) increased after the A->V training and decreased after the negative A->V training. We also confirmed that effective connectivity neurofeedback training (A->V) increases sound-induced visual illusion. We suggest that not only the amplitude of specific brain regions, but also the connectivity of them can be modulated using neurofeedback training.

- **Adaptation to delayed visual feedback is task-specific**
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Much has been learnt by examining how adaptation to displaced visual feedback about the position of the hand transfers to new positions and tasks. We examined adaptation to delayed visual feedback about the hand. We showed that people readily learn to intercept moving targets with a cursor that follows the hand with a delay of up to 200ms. Targets moved in different directions at different speeds, so people could not just learn to make specific movements. Adaptation transferred to movements starting at a different distance from the target. Moreover, having to pass through a moving gap to reach the moving target did not disrupt the adaptation. However, there was no transfer to lifting the hand as soon as the same target reached an indicated position, to moving the hand to arrive at a similar static target in synchrony with the third of three tones that were presented at equal intervals, to moving the hand to a static target through a moving gap, or to pursuing a moving dot with the unseen hand. Thus, adaptation to a temporal delay is task specific and can transfer to new circumstances but not to different tasks.

- **Hand actions to objects modulate visual attention: Evidence from lateralized ERPs**
S Kumar, M J Riddoch, G Humphreys (Department of Experimental Psychology, University of Oxford, United Kingdom; e-mail: sanjay.kumar@psy.ox.ac.uk)

We have shown that perceptual and motor-related ERP responses to objects are modulated by whether the objects are depicted with a congruent or incongruent hand grip. In this study we investigated whether attentional orienting is also influenced by hand actions to objects. We presented pictures of objects shown with a hand grip that was congruent or incongruent with the object's use. N2pc, an ERP component which reflects the allocation of spatial attention, was measured when target and distractor objects were presented in opposite visual fields. The N2pc was significantly smaller when target objects were congruently gripped for action and the irrelevant distractor objects was incongruently gripped, compared with other conditions, indicating that target selection was facilitated in this instance. In addition, an enhanced N2pc was apparent when target objects were incongruently gripped and distractor objects were congruently gripped, indicating that attentional selection of the target was slowed in this instance. The results indicate that the interaction between hands and objects is part of the visual unit that guides attention.

- **Optical correction reduces simulator sickness**

B Bridgeman (Psychology, University of California, CA, United States; e-mail: bruceb@ucsc.edu)

Prolonged work in driving simulators or virtual-reality environments is often complicated by simulator sickness, a feeling of nausea that can interfere with performance. Extensive work has been done on vestibular contributions to simulator sickness, but little attention has gone to visual contributions. A possible source of discomfort is the mismatch between distance to the screen in a driving simulator (56cm in our case of a 50° wide display) and depicted distances. We correct accomodation to slightly under infinity with +1.75 diopter spherical lenses. This correction, however, distorts the accomodative convergence to accomodation (AC/A) ratio, so we also introduce prisms to make parallel lines of sight converge at the screen distance. Subjects wore optometric test frames with spherical and prism correction in each eye, and drove for 40 minutes on a long figure-8 course with several driving environments. Control subjects wore the same test frames with two lenses in each eye that summed to 0 diopters, with no prism, to control for demand effects of wearing frames. Every 10 minutes they were asked for a vection and a comfort rating. Mann-Whitney U-tests showed significantly less discomfort in the correction condition, but vection ratings were the same in both groups.

TALKS : ART AND VISION

- **Effect of context on art experience and viewing behavior**

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Affective and cognitive aesthetic processes are influenced by contextual factors. Although art is appreciated in various different contexts, empirical research in psychological aesthetics was mainly conducted in the laboratory. We compared aesthetic experiences and viewing behavior in the museum and laboratory to examine the effect of context on art appreciation. In the first study, three groups of participants viewed artworks in the museum and/or the laboratory on two consecutive sessions while aesthetic experiences were measured via self-reports. In the second study, we additionally used mobile eye tracking to measure viewing time separately for artworks and labels. Our results suggest that aesthetic experiences are more arousing, positive and interesting in the museum than in the laboratory. Furthermore, artworks viewed in the museum were liked more and elicited a higher sense of understanding compared to artworks viewed in the laboratory. These effects were found regardless of whether artworks were seen before or after the laboratory session. Enhanced art experience was also significantly correlated with longer viewing time. However, context modulated the relationship between art experience and viewing time. Future research should focus on specific factors that contribute to this effect of museum context on aesthetic experience and viewing behavior.

- **Drawing from Life: Perceiving and reproducing complex, naturalistic curves**

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Accurate representational drawing underpins many aesthetic and scientific disciplines. Many studies of drawing use simple stimuli based on straight lines, circles or ellipses. Artists, though, know that living objects are made of complex, subtle curves, best exemplified by the nude human body used in art school 'life drawing' classes. Fourier synthesis can generate complex curves in two dimensions, combining sine waves of varied frequency, amplitude and phase in X and Y dimensions. When log(amplitude) linearly relates to log(frequency) then objects particularly resemble biological forms. Such abstract, curved stimuli can readily be generated so that they are 'simple' (i.e. the line doesn't cross itself). In this presentation we explore our findings with this powerful, generic class of stimuli. In our drawing studies participants copy the curves, either directly or from memory. In perceptual tasks we ask how curves are discriminated perceptually and are remembered. Analysis of drawn curves is not straightforward, but ratings of accuracy can be made by judges. The theoretically elegant approach of Michael Leyton in his Symmetry, Causality, Mind (1992), which he has used to analyse paintings and drawings, can also be used to parse curves according to their M+, M-, m+ and m- maxima and minima.

- **Is there a logic in the 'neoplasticism' compositions of Piet Mondrian?**
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What is beauty? Can universal aspects of aesthetics be captured by composition rules? In the tradition of experimental aesthetics (Fechner, 1876) we are interested in the compositional rules behind a confined set of some of the most iconic paintings of the 20th century - the austere geometric patterns of Piet Mondrian who coined the name 'Neoplastic Abstraction' for his works between 1921 and 1939. A systematic analysis of the geometric and colour relationships of the small number of objects used in a pattern (horizontal and vertical lines, patches of colour filled with a small set of 'primary' colours) provides a unique description of each individual painting with a small number of parameters. This database was used (a) by means of statistical analysis, to get a better idea of the regularities of the compositions used by Piet Mondrian, and (b) to generate artificial look-alikes of Mondrian paintings ('Mondri-Makes') that are used to test experimentally the solution space for possible compositions with regards to aesthetic preference (Holmes & Zanker, i-Perception 3 (7), 2012)

- **Symmetry is forever**
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Pleasant and unpleasant events, as well as arousal, may influence the experience of duration. We investigated how preference for abstract visual patterns is related to their physical and perceived duration. Physical duration varied between 0.5s and 1.5s. Visual stimuli were squares containing black and white elements, and belonged to one of two classes: random and symmetrical. Each stimulus was only presented once. We manipulated perceived duration using a click train (5Hz) and compared it to white noise and to silence (Penton-Voak et al., 1996). In different sessions, participants (N=24) rated duration and preference. Clicks did increase perceive duration, and symmetry was preferred to random, as expected. Within each of the three sound conditions, symmetry was perceived as lasting longer than random. In addition, within random stimuli preference was negatively correlated to perceived duration. Within symmetric stimuli, preference was positively correlated to perceived duration. In terms of physical duration, preference for random patterns decreased with duration and preference for symmetric patterns increased with duration. We have found, therefore, a case in which beautiful stimuli appear to last longer than less beautiful stimuli, and the longer they last the more they are preferred.

TALKS : BRAIN RHYTHMS

- **Modeling the effect of spontaneous electrophysiological oscillations on visual perception**
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The brain is never at rest even in the absence of experimental events. How does this spontaneous brain activity interact with the processing of external stimuli? Ongoing alpha oscillations, as observed with electroencephalography (EEG), impair detection of sensory stimuli, but little is known about the perceptual mechanisms of this impairment. Studying these mechanisms requires a better understanding of the psychophysical effects of alpha oscillations from a modeling perspective. To study prestimulus alpha oscillations, we recorded EEG signals while observers performed signal detection tasks with stimuli of different contrast intensities. We used independent component clustering to isolate alpha activity originating specifically from posterior cortices and to dissociate them from the more anterior sensory-motor mu rhythm that occurs in the same frequency band. The effect of prestimulus posterior alpha oscillations on detection performance was analyzed by fitting different gain models to the psychometric functions obtained under strong or weak prestimulus alpha oscillations. The model fits show that prestimulus alpha oscillations exert their inhibitory effect by modulating the gain of the psychometric function, resembling the well-studied psychophysical effect of spatial attention on contrast sensitivity.

- **Evidence for Attentional Sampling in the MEG Gamma Band Response**
  A Landau, H Schreyer, S van Pelt, P Fries (ESI for Neuroscience in Cooperation with MPS, Germany; e-mail: ayelet.landau@gmail.com)

Overt exploration behaviors, such as whisking, sniffing, and saccadic eye movements are often characterized by a theta/alpha rhythm. In addition, the electrophysiologically recorded theta or alpha phase predicts global detection performance. These observations raise the intriguing possibility that covert selective attention samples from multiple stimuli rhythmically. Previously we found that following a reset event to one location, detection performance fluctuated rhythmically. Additionally, different locations were associated with opposing phases of the rhythmic sampling. This suggests that selective attention entails exploration rhythms similar to other exploration behaviors. Spatial attention has been mechanistically linked to gamma band activity in visual brain regions. Gamma synchronization is a proposed mechanism supporting inter-areal communication of attended stimuli. Here, we used MEG to identify bilateral sources of gamma induced by two corresponding contralateral stimuli. We found that gamma band-limited power fluctuated at a theta/alpha rhythm, and the phase of this fluctuation predicted behavioral outcome. Importantly, different behavioral outcomes were preceded by opposing phases of the theta/alpha fluctuations. These findings provide further support for the idea that attention to multiple locations is supported by sequential sampling and suggest a functional role for cross frequency coupling between sustained gamma band response and lower frequencies in the theta/alpha range.

- **A unified framework for local population frequency responses in the human visual system**
  E Podvalny[1,2], H Michal[2], N Noy[1,2], S Bickel[3,8], E M Zion-Golumbic[4,7], I Davidesco[5], G Chechik[6], C E Schroeder[4,7], A Mehta[8], M Tsodyks[1], R Malach[1] ([1]Department of Neurobiology, Weizmann Institute of Science, Israel; [2]Gonda Multidisciplinary Research Center, Bar-Ilan University, Ramat-Gan, Israel; [3]Department of Neurology, Albert Einstein College of Medicine, Bronx, NY, United States; [4]Department of Psychiatry, Columbia University College of Physicians and Surgeons, NY, United States; [5]Interdisciplinary Center for Neural Computation, Hebrew University, Israel; [6]Gonda Multidisciplinary Brain Research Center, Bar-Ilan University, Ramat-Gan, Israel; [7]Cognitive Neuroscience and Schizophrenia Program, Nathan Kline Institute, Orangeburg, NY, United States; [8]Comprehensive Epilepsy Center, Hofstra North Shore-LIJ School of Medicine, New Hyde Park, NY, United States; e-mail: ellapodvalny@gmail.com)

The role of specific oscillatory bands, such as the gamma-band activity in the local field potential has been a central topic of research. This rhythmic, synchronous activity emerges on top of asynchronous activity that underlies the power scaling inversely to the frequency ($p \propto 1/f^{\chi}$). In the present work, we aimed to explore whether the asynchronous and the oscillatory activity modulated by visual stimulus within a single framework. We used electrocorticographic recordings from human cortex during visual stimulation. We extracted the $1/f^{\chi}$ component by coarse graining spectral analysis and computed the exponent χ in broad frequency range (10-100 Hz). For the remaining part of the spectrum, which contained mostly oscillatory activity, we computed the height and the frequency of oscillatory peaks. We found the exponent χ is modulated by visual stimulus and decreases during visual stimulation. The height of the high- frequency oscillatory peaks was significantly correlated to exponent χ on visual stimulation condition. These two phenomena account for both high-frequency power increase and low-frequency power decrease associated with the visual response - and suggest that these apparently diverse phenomena may be driven by a common mechanism.

- **Alpha, gamma and haemodynamic responses –how are they related?**
  S Haigh[1], N Cooper[2], V Romei[2], A Wilkins[2] ([1]Department of Psychology, Carnegie Mellon University, PA, United States; [2]Department of Psychology, University of Essex, United Kingdom; e-mail: shaigh@andrew.cmu.edu)

We measured the oxyhaemoglobin response to grating patterns using near-infrared spectroscopy and simultaneously, the associated change in gamma and alpha power in the electroencephalogram. Of the 22 participants, 6 had migraine. We presented square-wave grating patterns (1) with bars alternating in colour, or (2) with achromatic bars that were static, drifted at a constant velocity towards central fixation, or had a vibrating motion with similar contour velocity. For the chromatic gratings, regardless of hue, those with large separation in the chromaticity of the bars evoked a relatively large oxyhaemoglobin response, greater alpha suppression, and a lower gamma power. For achromatic gratings, the moving patterns (drifting and vibrating) evoked a shorter oxyhaemoglobin response, and greater alpha suppression than the static pattern. The gamma response was inconsistent. Migraineurs, who generally have a hyper-responsive cortex, showed a larger-amplitude/shorter-duration oxyhaemoglobin response and greater alpha suppression to the same gratings, but did not show consistently different gamma responses. The association between oxyhaemoglobin response and alpha suppression may reflect the extent of cortical activation by a stimulus. The gamma response, however, is less consistent.

TALKS : TEMPORAL PROCESSING

- **Remote temporal camouflage**
  J Cass[1], E Van der Burg[2] ([1]Psychology, University of Western Sydney, Australia; [2]University of Sydney, Australia; e-mail: johncassvision@gmail.com)

Humans are capable of differentiating and sequencing events at multiple temporal scales. At the coarsest scales (seconds-minutes) temporal judgments rely on episodic memory systems. At finer temporal scales we gain direct perceptual access to the timing of stimulus events. Here we show that our precision for making visual simultaneity and temporal order judgments can be severely corrupted by more than a factor of four due to the mere presence of abrupt visual events located elsewhere in the visual field. This effect we refer to as Remote Temporal Camouflage (RTC) occurs even when target elements are separated from distractor events by large spatial and temporal distances. These interference effects have a unique spatial distribution conforming to neither the predictions of attentional capture by transient events, nor by stimulus dependencies associated with other contextual phenomena such as crowding, object-substitution masking or motion-induced blindness. These dependencies combined with the absence of RTC under cross-modal (audio-visual) target conditions suggest it is likely to result from interactions between and/or compulsory integration within long-range visual motion mechanisms.

- **Temporal recalibration involves adaptation at two time scales**
  D Alais[1], J Cass[2], E Van der Burg[1] ([1]School of Psychology, University of Sydney, Australia; [2]Psychology, University of Western Sydney, Australia; e-mail: david.alais@sydney.edu.au)

We investigate the time constant of recovery from adaptation to temporal asynchrony. Subjects adapted to a 4 min naturalistic animation with strong audiovisual temporal cues. The soundtrack was asynchronous by either +/- 200 ms. For 2 min postadaptation, we sampled synchrony perception every 2 s with a flash/beep stimulus that varied over several ±SOAs. Binning synchrony responses within a short, rolling time window we estimated the PSS during recovery from temporal adaptation. Rolling average PSSs showed significant recalibration initially followed by a recovery function, with PSSs returning to baseline after 60 s. We also analysed short-time scale recalibration by testing for adaptation effects between successive synchrony probes. Although these probes were brief (60 ms), we found that a given synchrony judgment during postadaptation was strongly influenced by the previous synchrony probe's sign, showing adaptation in the direction of the preceding probe's SOA. Together, these results show long- and short-scale temporal recalibration, with the short-scale inter-probe effects superimposed on long-scale recalibration. In a second experiment, we delayed the synchrony probes for 60 s postadaptation and observed no long-scale recalibration, showing there is no storage of long-scale temporal adaptation.

- **Asymmetries in visuomotor recalibration of time perception: Does causal binding distort the window of integration?**
  M Rohde, L Greiner, M Ernst (Cognitive Neurosciences, Bielefeld University, Germany; e-mail: marieke.rohde@uni-bielefeld.de)

There is a causal asymmetry in visuomotor timing depending on which modality leads the temporal order; a lagging visual stimulus may be interpreted as causally linked sensory feedback, a leading visual stimulus not. We tested whether this asymmetry leads to directional asymmetries in temporal recalibration of an interval estimation task. Participants were trained with three temporal discrepancies between a motor action (button press) and a visual stimulus (flashed disk): 100ms vision-lead, simultaneity, and 100ms movement-lead. They then estimated a range of intervals between flash and press by adjusting a point on a visual scale. We found that temporal recalibration occurs nearly exclusively on the movement-lead side of the range of discrepancies (uni-lateral lengthening or shortening of the window of temporal integration), but no asymmetries in recalibration of the point of subjective simultaneity (PSS) or discriminability. This seeming contradiction (symmetrical recalibration of PSS, asymmetrical recalibration of interval estimation) poses a challenge to models of temporal order perception that assume a time measurement process with Gaussian noise. Simulations of a two-criterion model of temporal integration illustrate that a possible compressive bias around perceived simultaneity (temporal integration) even prior to perceptual decisions about order/simultaneity would be difficult to detect in the responses.

- **Time and making perceptual decisions**
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In models of perceptual decision making within the classical signal processing framework (e.g. integration-to-bound), time is used to accumulate evidence. In probabilistic, sampling-based frameworks, time is necessary to collect samples from subjective posterior distributions for the decision. Which role is dominant during perceptual decisions? We have analytically derived the progression of the error and subjective uncertainty in time for these two models of decision making, and found that they show a very differently evolving pattern of the correlation between subjects' error and their subjective uncertainty. Under sampling, after a brief initial period, the correlation always increases monotonically to an asymptote with this increase continuing long after the error itself has reached its asymptote. In contrast, integration-to-bound shows increasing or decreasing changes in correlation depending on the posterior's kurtosis, and with additive behavioral noise, the correlation decreases. We conducted a decision making study where subjects had to perform time-limited orientation matching and report their uncertainty about their decisions, and found that the results confirmed both predictions of the sampling-based model. Thus, under typical conditions, time in decision making is mostly used for assessing what we really know and not for gathering more information.

TALKS : MULTISTABILITY AND RIVALRY

- **Oddballs that are suppressed or dominant in binocular rivalry are equally processed for the first 300 ms**
  U Roeber[1], B N Jack[1], R P O'Shea[1], A Widmann[2], E Schröger[2] ([1]Psychology, Southern Cross University, Australia; [2]Institute for Psychology, University of Leipzig, Germany; e-mail: urte@uni-leipzig.de)

We married two techniques to investigate change detection in early binocular processing: binocular rivalry and oddball stimulation. Binocular rivalry yields unpredictable changes in perception between a continuously-presented image to the right eye and a continuously-presented, different image to the left eye. Oddball stimulation occurs when a standard stimulus is repeatedly presented but occasionally replaced by another, deviant stimulus. Deviants elicit larger negative responses in event-related potentials (ERPs)—the visual mismatch negativity (vMMN)—even when stimulation is not attended. We presented binocular-rivalry stimuli repeatedly for 100 ms on and 100 ms off. Standards were full-contrast, dichoptic, orthogonal gratings; deviants were identical except with reduced contrast and luminance in one eye. Because of binocular rivalry these deviants occurred either to the suppressed or to the dominant eye. We found that, compared to standards, ERPs to deviants showed more negativity at 130 ms and at

270 ms; these are candidate vMMNs. They were of similar amplitude in the dominant eye and in the suppressed eye. Differences in processing between the two types of deviants emerged only after 300 ms. We propose that oddball stimuli are fully processed during binocular rivalry, irrespective of whether they are perceived or not.

- **Effects of reinforcement on binocular rivalry**
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Binocular rivalry is a phenomenon where the simultaneous presentation of two different stimuli to the two eyes leads to alternating perception of the two stimuli. The temporary dominance of one stimulus over the other is influenced by several factors. Here we hypothesized that increasing the subjective value of one stimulus via reinforcement should lead to a relative increase of its dominance duration. Orthogonal red and blue rotating grating stimuli were shown continuously, while monetary reward was applied repeatedly during the conscious perception of one stimulus but not the other. To rule out a subjective bias in reporting perception, periods of perceptual dominance were assessed objectively using two different approaches: in a behavioural experiment, perceptual dominance was inferred from behavioural performance in a supplementary target detection task. In a second functional magnetic resonance imaging experiment, perceptual dominance was decoded from neural activations in visual cortex using multivariate pattern analysis. Both experiments demonstrate an increase of dominance duration of the rewarded stimulus. These results indicate an influence of value learning on inferential processes in perception.

- **Long-term persistent state in vision**
  M Wexler, M Duyck, P Mamassian (Laboratoire Psychologie de la Perception, CNRS & Université Paris Descartes, France; e-mail: mark.wexler@parisdescartes.fr)

Low- to mid-level vision is usually thought of as a stateless input-output process, or as involving state that persists over seconds or at most minutes, as in adaptation or multistability phenomena. Here we document two visual state parameters with much longer state dynamics. We study two stimuli, both involving depth perception from motion, whose perception is affected by strong biases in nearly every observer. These biases are continuous, angular variables that can be inferred robustly from binary perceptual reports on multiple bistable stimuli. In an experiment on about 700 subjects, we have measured population distributions of these two biases. Both distributions have local peaks in the cardinal directions and are significantly non-uniform, but are otherwise different and uncorrelated. About 250 subjects repeated the experiment two weeks later, and most had nearly unchanged biases; the median change was only 8 and 11 deg in the two parameters. In spite of this apparent stability, we also show that these biases can fluctuate spontaneously, after viewing many hundreds of stimuli but also after periods in darkness.

- **Interpreting the temporal dynamics of perceptual rivalries**
  R Gallagher[1], H Haggerty[2], D H Arnold[3] ([1]School of Psychology, University of Queensland, Australia; [2]School of Mathematics, University of Queensland, Australia; [3]Perception Lab, University of Queensland, Australia; e-mail: regan.gallagher@uqconnect.edu.au)

Perceptual rivalries are situations wherein the content of awareness alternates despite constant stimulation. For instance, in binocular rivalry awareness switches intermittently between stimuli presented to the right or left eye, such that only one image is seen at a time. In motion-induced blindness, typically salient static dots can seem to disappear when placed in close proximity to motion. One observation that has been used to argue for a common causal mechanism is that the dynamics of diverse perceptual rivalries can be similar on an individual basis. If, for example, a participant reports rapid changes during binocular rivalry, they are also likely to report rapid changes during motion-induced blindness. We assessed this relationship by also having people report on the visibility of unexpected physical stimuli (an intermittent gabor presented in noise). We find that the dynamics of perceptual rivalries are well predicted by the speed at which participants report seeing unexpected changes, and by the tendency to over- or under-report seeing unambiguous physical stimuli. We suggest that the dynamics of diverse forms of perceptual rivalry likely reflect subjective criteria used when reporting on the dynamics of unexpected changes, and thus do not provide strong evidence for a common causal mechanism.

- **Altered operating regimes of multi-stable perception**
  J Braun[1], A Pastukhov[1], G Deco[2] ([1]Center for Behavioral Brain Sciences, Otto von Guericke University Magdeburg, Germany; [2]Center for Brain and Cognition, University Pompeu Fabra, Spain; e-mail: jochen.braun@ovgu.de)

We reported recently [Pastukhov et al., 2013, Front. Comput. Neurosci., 7(17)] that multi-stable perception operates in a consistent and functionally optimal dynamical regime, balancing the conflicting goals of stability and sensitivity. In that work, we deduced the operative balance of stabilizing and destabilizing factors – competition, adaptation, and noise – from the reversal statistics of individual observers (mean and variance of dominance time, correlation and time-constant of history-dependence) with the help of a simple computational model. To further validate this approach, we investigated two conditions where reduced adaptation (wobbling vs. stationary axes of rotation in a kinetic depth display) or enhanced competition (titled vs. vertical axes) is expected. Both manipulations altered reversal statistics significantly. The computational analysis revealed reduced adaptation in the case of wobbling vs. stationary axes, and enhanced competition in the case of tilted vs. vertical axes, exactly as predicted. Our results confirm that multi-stable dynamics is well described by a balance of competition, neural adaptation and neural noise. They further show that the reversal statistics of individual observers faithfully reflects both normal and altered operating regimes of multi-stable perception. In conclusion, we demonstrate a sensitive diagnostic for perceptual dynamics with potential applications for developmental and patient populations.

- **Multisensory mechanisms for perceptual disambiguation. A classification image study on the stream-bounce illusion**
  C V Parise[1], M Ernst[2] ([1]Max Planck Institute and Uni Bielefeld, Germany; [2]Cognitive Neurosciences, Bielefeld University, Germany; e-mail: cesare.parise@uni-bielefeld.de)

Sensory information is inherently ambiguous, and observers must resolve such ambiguity to infer the actual state of the world. Here, we take the stream-bounce illusion as a tool to investigate disambiguation from a cue-integration perspective, and explore how humans gather and combine sensory information to resolve ambiguity. In a classification task, we presented two bars moving in opposite directions along the same trajectory, meeting at the centre. Observers classified such ambiguous displays as streaming or bouncing. Stimuli were embedded in audiovisual noise to estimate the perceptual templates used for the classification. Such templates, the classification images, describe the spatiotemporal noise properties selectively associated to either percept. Results demonstrate that audiovisual noise strongly biased perception. Computationally, observers' performance is well explained by a simple model involving a matching stage, where the sensory signals are cross-correlated with the internal templates, and an integration stage, where matching estimates are linearly combined. These results reveal analogous integration principles for categorical stimulus properties (stream/bounce decisions) and continuous estimates (object size, position...). Finally, the time-course of the templates reveals that most of the decisional weight is assigned to information gathered before the crossing of the stimuli, thus highlighting a predictive nature of perceptual disambiguation.

TALKS : FUNCTIONAL ORGANISATION OF THE CORTEX

- **Combined functional and diffusion-weighted magnetic resonance imaging reveals temporal-occipital network involved in auditory-visual object perception**
  A L Beer[1], T Plank[1], G Meyer[2], M W Greenlee[1] ([1]Experimental Psychology, University of Regensburg, Germany; [2]Experimental Psychology, University of Liverpool, United Kingdom; e-mail: anton.beer@psychologie.uni-regensburg.de)

Multisensory object perception involves various brain areas in the superior temporal and occipital cortex. We examined ten healthy people with combined functional magnetic resonance imaging (MRI) and probabilistic fiber tracking based on diffusion-weighted MRI in order to investigate the white matter connectivity of this multisensory processing network. During functional examinations observers viewed either movies of lip or body movements, listened to corresponding sounds (speech sounds or body action sounds), or a combination of both. We found that bimodal stimulation engaged a temporal-occipital network of brain areas including the multisensory superior temporal sulcus (STS). Fiber tracking revealed white matter tracks between the auditory and the medial occipital cortex, the STS, and the inferior occipital cortex. However, limited overlap was observed in the STS between terminations of the auditory white matter tracks and the functional activity. Instead region-by-region tracking showed that

the multisensory STS region was connected to primary sensory regions via intermediate nodes in the superior temporal and inferior occipital cortex. Our findings suggest that multisensory object processing relies on a brain network in the superior temporal and inferior occipital cortex that is best revealed by combining functional and diffusion-weighted MRI methods.

- **Functional connectivity predicts face selectivity in the fusiform gyrus**
  L Garrido, K Nakayama (Harvard University, MA, United States;
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Saygin and colleagues (2012) recently showed that patterns of anatomical connectivity of voxels in the fusiform gyrus (FG) predicted face selectivity. Here, we show that the pattern of functional connectivity using resting-state also predicts FG face selectivity. We tested 20 participants using fMRI resting-state and functional "localizers". For each participant, we computed the correlation between the time-course of FG voxels and 84 other brain regions. We also computed the face selectivity for each FG voxel. We aimed to predict the face selectivity of FG voxels for participant X, using functional connectivity patterns of each voxel in that participant. We used linear regression with the remaining participants to estimate the contribution of the functional connectivity to face selective responses. The resulting parameters were applied to predict the face selectivity of each FG voxel in participant X. Finally, we compared the predicted face selectivity to the actual face selectivity. This procedure was repeated for each participant. We were able to significantly predict face selectivity in 17 out of the 20 participants. These results allow us to (1) identify brain regions that contribute to face selectivity, and (2) use these methods to estimate face selectivity in participants who cannot perform functional localizers.

- **Tool Manipulation Knowledge is Retrieved by way of the Ventral Visual Object Processing Pathway**
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Visual object processing is organized into two functionally independent visual pathways. The dorsal visual stream subserves object-directed action, and the ventral visual stream subserves visual object recognition. The neural representation of manipulable objects offers an unique window into interactions between the ventral and dorsal visual streams. Here we show, using fMRI, that object manipulation knowledge is accessed by way of the ventral object processing pathway. We exploit the fact that parvocellular channels project to the ventral but not the dorsal stream, and find that increased neural responses for tool stimuli are observed in the inferior parietal lobule when those stimuli are visible only to the ventral object processing stream. For stimuli titrated so as to be visible by the dorsal visual pathway (through koniocellular inputs), tool-preferences were observed in superior and posterior parietal regions. Functional connectivity analyses confirm the dissociation between sub-regions of parietal cortex according to whether their principal afferent input is via the ventral or dorsal visual pathway. These results challenge the embodied hypothesis of tool recognition, as they show that activation of parietal regions that process object manipulation is contingent on processing within the ventral pathway.

- **Top-down attending to and bottom-up detection of multiple simultaneously presented targets are governed by the right IPS**
  B de Haan, H-O Karnath (Center of Neurology, University of Tuebingen, Germany;
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The ability to respond to multiple simultaneously presented targets is an essential and distinct human skill, as is dramatically demonstrated in stroke patients suffering from visual extinction. The neural correlates underlying this ability are the topic of continuing debate, with some studies pointing towards the TPJ whereas other studies suggest a role for the IPS. We performed an fMRI study to test the hypothesis that whereas the IPS is associated both with the top-down direction of attention to multiple target locations and the bottom-up detection of multiple targets, the TPJ is predominantly associated with the bottom-up detection of multiple targets. We used a cued target detection task with a high proportion of catch trials to separately estimate top-down cue-related and bottom-up target-related neural activity. Both cues and targets could be presented unilaterally or bilaterally. We performed conjunction analyses to determine the neural anatomy specifically associated with bilateral situations. Whereas we found no evidence of target-related neural activation specific to bilateral situations in the TPJ, we found both cue-related and target-related neural activation specific to bilateral situations in the right IPS, suggesting

that both top-down attending to and bottom-up detection of multiple simultaneously presented targets are governed by the right IPS.

- **Topographic representation of numerosity in human parietal lobe**
  B Harvey[1], B Klein[1], N Petridou[2], S Dumoulin[1] ([1]Experimental Psychology/Helmholz Institute, Utrecht University, Netherlands; [2]Department of Radiology, University Medical Center Utrecht, Netherlands; e-mail: b.m.harvey@uu.nl)

Numerosity, the set size of a group of items, is processed by association cortex, but certain aspects mirror properties of primary senses (Dehaene, 1997; Burr and Ross, 2008). Sensory cortices contain topographic maps reflecting the structure of sensory organs such as the retina, cochlea or skin. Is the cortical representation and processing of numerosity organized topographically, even though no sensory organ has a numerical structure? Using high-field fMRI (7T) and custom-built model-based analysis that captures numerosity tuning using population receptive field methods (Dumoulin and Wandell, 2008), we describe neural populations tuned to small numerosities (within the subitizing range) in human parietal cortex. These neural populations are organized topographically, forming a numerosity map where preferred numerosity increases from medial to lateral cortex. This numerosity map is robust to changes in low-level stimulus features. Furthermore, the cortical surface area devoted to specific numerosities (cortical magnification factor) decreases with increasing numerosity, and the tuning width is proportional to preferred numerosity. These organizational properties mirror key features of sensory and motor topographic maps, extending topographic principles to representation of higher-order abstract features in association cortex and supporting the analogy between numerosity and other senses.

- **Effects of adaptation on numerosity decoding in the human brain**
  D Aagten-Murphy[1], E Castaldi[2], M Tosetti[3], D Burr[1], M C Morrone[4] ([1]University of Florence, Italy; [2]Department of Neurofarba, University of Florence, Italy; [3]Laboratory of Magnetic Resonance, IRCCS Foundation Stella Maris, Italy; [4]University of Pisa, Italy; e-mail: david.aagtenmurphy@gmail.com)

Psychophysical studies suggest that the perception of numerosity is susceptible to adaptation. Neuroimaging studies have reported habituation of BOLD signals in the intra-parietal sulcus (IPS), a region clearly involved in the representation of number. Here we tested whether adapting to a dot-pattern of specific numerosity can selectively modify neural coding for numerosity, measuring BOLD responses from all of visual cortex after adaption with a novel paradigm (verified psychophysically). Unlike standard BOLD habituation, we spaced adaptor and test stimuli 20 seconds apart to disentangle their BOLD responses. We then applied multivariate pattern classifiers (SVM) to the BOLD responses to random-dot patterns (20-80 dots, equated for total contrast energy), before and after adaptation to 80 dots. Before adaptation, classifiers for IPS – but not V1 – accurately discriminated numerosity over the whole range. Classifiers applied to post-adaptation trials also decoded numerosity accurately in IPS. However, pre-adaptation classifiers failed to classify accurately post-adaption responses, with systematic misclassifications. All results are consistent with the notion that adaptation to number selectively affects higher-order representations of numerosity magnitude rather than early visual areas.

TALKS : EMOTION

- **Automatic influence of irrelevant affect on confidence judgments**
  A Chetverikov (Department of Psychology, St.Petersburg State University, Russian Federation; e-mail: stop.psy@gmail.com)

Growing evidence suggests that error-monitoring is tightly related to emotions. Specifically, negative affect increases error-related negativity, a negative deflection on electroencephalography observed after making an error [Wiswede et al, 2009, Neuropsychologia, 47(1), 83-90]. We hypothesized that affect also influences confidence judgments, which measure subjective probability of error. Experiment followed a 2x2x2, Condition X Subjective Attractiveness (SA) X Objective Attractiveness (OA), mixed-measures design. Subjects (N=42) were shown photographs of faces and made an attractive or unattractive judgment (SA). Faces were selected on the basis of previous experiment: half was attractive and the other half was unattractive (OA). Then, a pair of playing cards was shown consequently (60 ms first card, pre- and post-mask, 500 ms second card). Subjects made same or different judgments and rated confidence. In the "affect attribution" condition they were asked to control for the influence of attractiveness on confidence and in control condition no such instruction was given. The results demonstrated that subjects were more confident after seeing attractive faces as compared to unattractive ones regardless of the condition. This effect holds both for SA and for OA. Thus, the study shows the involvement of affect in automatic error-monitoring process measured by confidence ratings.

- **How does self-relevance impact perceptual decision-making about uncertain emotional expressions? Diffusion modeling applied to experimental data**
  M El Zein, V Wyart, J Grèzes (Laboratoire des Neurosciences Cognitives, Ecole Normale Supérieure INSERM U960, France; e-mail: marwaelzein7@gmail.com)

The ability to correctly decode others' emotional expressions and to rapidly and accurately select the most relevant course of action bears survival advantages. Such ability depends not only on the proper identification of the emitted signal, often complex or ambiguous under natural settings, but also on the evaluation of its significance for the observer. Particularly, an angry face is more relevant when looking towards an observer who becomes the target of the threat, whereas a fearful face looking away from the observer may signal a potential threat in the periphery. Here, we aim to identify the mechanisms underlying decision-making about facial expressions of emotions and the impact of self-relevance on these mechanisms. We manipulated parametrically the intensity of emotional expressions and their self-relevance (direct or averted gaze) during a fear-anger categorization task. We applied diffusion-to-bound models on the behavioral data to determine: 1) whether decisions made upon emotional content are formed by continuously accumulating sensory evidence, and 2) how self-relevance alters decision-making, either by influencing the accumulation rate or by adjusting the decision bound. Our preliminary data suggest that self-relevance biases decisions by shifting the decision bound in response-selective, not stimulus-selective structures.

- **Integration of kinematic components in the perception of emotional facial expressions**
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The idea that complex facial or body movements are composed of simpler components (usually referred to as 'movement primitives' or 'action units') is common in motor control (Chiovetto et al. 2010) as well as in the study of facial expressions (Ekman & Friesen, 1978). However, such components have rarely been extracted from real facial movement data. METHODS: We estimated spatio-temporal components that capture the major part of the variance of dynamic facial expressions, using a motion retargeting model for 3D facial animation (Curio et al, 2010) and applying dimension reduction methods (NMF and anechoic demixing). The estimated components were used to generate artificial stimuli, assessing the minimal required number of components in a perceptual Turing test, and their contributions to expression classification and expressiveness ratings. RESULTS: For an anechoic mixing model two components were sufficient for perfect reconstruction of the original expression. Often one component is sufficient for classification, while ratings tend to depend gradually on two, or more components.
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- **Enhanced visual detection in trait anxiety under perceptual load**
  N Berggren, T Blonievsky, N Derakshan (Birkbeck University of London, United Kingdom; e-mail: nbergg01@mail.bbk.ac.uk)

A classic debate in anxiety research is whether high anxiety is associated with enhanced visual attention, to allow monitoring of the visual environment for potential threats, or whether increased negative affect and arousal in anxiety lead to narrowing of attention. Previous results have been inconsistent, mainly due to the manipulation of anxiety within participants through mood induction techniques. Here, we asked whether self-report levels of trait/dispositional anxiety would demonstrate clearer evidence of enhanced or narrowed attention. Participants completed a visual search task of varying levels of perceptual load, while also instructed to detect whether an additional small stimulus appeared on trials. Anxiety did not modulate performance in the primary search task at any level of load, and did not affect critical stimulus (CS) detection under low load. We also replicated the standard finding that as load increased, CS detection dropped in a linear fashion. Importantly however, under high load, anxiety correlated with superior sensitivity for the CS, with shallower slope declines in sensitivity as load increased. These results provide the first direct evidence for increased perceptual capacity in trait anxiety, suggesting that a disposition to experience high levels of anxiety is associated with a hypervigilant mode of visual processing.

- **Primes and targets of different strengths in animal phobia: A generalized accumulator model**
  T Schmidt, A Haberkamp (Department of Experimental Psychology, University of Kaiserslautern, Germany; e-mail: thomas.schmidt@sowi.uni-kl.de)

In response priming tasks, speeded responses are performed toward target stimuli preceded by prime stimuli. Responses are slower and error rates are higher when prime and target are assigned to different responses, compared to assignment to the same response, and those priming effects increase with prime-target SOA. Here, we generalize Vorberg et al.'s (2003, PNAS 100, 6275-80) accumulator model of response priming, where response activation is controlled exclusively by the prime until target onset, and then taken over by the actual target. Priming thus occurs by motor conflict because a response-inconsistent prime can temporarily drive the process towards the incorrect response. While the original model assumed prime and target signals to be identical in strength, we allow different rates of response activation (cf. Mattler & Palmer, 2012, Cognition 123, 347-360). We use the model to quantify how spider-fearful, snake-fearful, and control participants differ in their response activations by fear-related vs. neutral images of primes or targets. Our model correctly predicts that priming effects increase with prime strength but decrease with target strength, and that overall response times decrease with target strength, consistent with the idea that fear-related stimuli provide more vigorous response activation than neutral ones.

- **The experience of beauty of living beings and artificial objects**
  S Markovic, I Sole (Laboratory for Experimental Psychology, University of Belgrade, Serbia; e-mail: smarkovi@f.bg.ac.rs)

The purpose of the present study was to compare the underlying structures of the subjective experience of beauty of two wide categories of objects – living beings and artificial objects. In Preliminary study 1 two sets of six photographs were selected: (a) living beings (humans, animals, plants) and (b) artificial objects (buildings, interiors and objects of everyday use). In Preliminary study 2 a set of eighty representative descriptors of the subjective experience of beauty was selected (e.g. pleasant, cute, magnificent etc). In the main study twenty-one participants judged two sets of stimuli using a check-list of eighty descriptors. Factor analyses extracted different dimensions for two categories. (a) Living beings: Fascination, Cuteness, Relaxation, Cheerfulness and Attractiveness; (b) Artificial objects: Fascination, Grandiosity, Sophistication and Good design. These results have shown that the Fascination was the only common dimension, while the others were category specific. The structure of the experience of beauty was more emotionally focused in the case of living beings (Cuteness, Relaxation, Cheerfulness and Attractiveness), whereas it was more focused to the perceptual and formal aspects of the artificial object's beauty (Grandiosity, Sophistication, Good design).

AUTHOR INDEX

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